

AGRICULTURAL ENGINEERING

The Journal of the American Society of Agricultural Engineers

MARCH 1930

Economic Justification for Reclamation
Activities *Dr. Elwood Mead*

The Engineering Factor in Land
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The Rehabilitation of Irrigation Dis-
tricts *W. W. McLaughlin*

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Economic Justification for Land Reclamation Activities¹

By Dr. Elwood Mead²

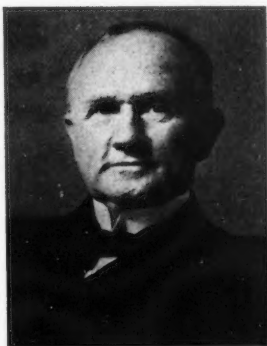
IT IS an appreciated privilege to be able to attend this meeting of the American Society of Agricultural Engineers. I was one of its earliest members, am now an honorary member, and I have watched its growth in numbers and influence with peculiar satisfaction. Your invitation gives me an opportunity to outline some of the triumphs of the agricultural engineer in the conquest of the arid region. In one-third of the country, in seventeen states, the reclamation achievements of the agricultural engineer have added immensely to the national wealth, greatly improved the conditions of life and given to the western third of the country a new outlook.

Speculative Reclamation a Myth. Before dealing with the economic achievements of reclamation, I wish to refer to references which have been made to speculation as an active instrument in carrying out reclamation development. Those who think speculation has anything to do with reclamation development, public or private, don't understand conditions. Every influence is against it. The farm population of this nation has decreased nearly five million in the last nine years. There was a net movement from the farms to the cities of more than half a million people last year. In the older developed and prosperous parts of the country, there is a continuous movement towards the cities, with a decline in the price of farm lands.

In the arid region the cost of providing water has grown with the loss of opportunities for cheap diversion. We can no longer depend on the natural flow of streams, but must rely largely on stored water. Building reservoirs is costly. Today there is no project being carried on, where the cost of providing water is less than \$100 an acre, and in some it rises to \$200 an acre. These outlays have to be made before there can be any return. Promoters and speculators are not looking for that sort of enterprise. They are out for profit, and no one but a fool could hope for any immediate returns from reclamation.

As a result, reclamation by private enterprise has practically ceased. It is being carried on by the federal government, and where it can be carried on in connection with power development because of the advantages, both local and national, but for this kind of development there was never a greater need for its continuance or never a time when its national value was greater than now.

There is another reason why speculative development has entirely disappeared. In the early days speculation thrived on an unreasonable inflation of land prices. That is no longer possible. Following the investigations of 1924 carried on by former Secretary of the Interior Garfield



Dr. Elwood Mead

of Ohio, Julius Barnes of Minnesota, Dr. Widtsoe of Utah, and others, the economic and social relations of irrigation were given a thorough and impartial review, and as a result, laws were passed which require privately owned land to be appraised before irrigation works are built. Its value without irrigation is fixed, and the owners are required to sell at that value. Under this on the Kittitas development now being carried on in Washington private land is being sold for \$2.50 an acre, which is far less than the local and state taxes which have been paid on it since the present owners acquired it. Before any project can be undertaken now, there must be not only an estimate of the engineering costs but a study of soils, a study of markets, a study of the cost of changing raw land into farms, and of the kind of

agriculture and kind of equipment these farms should have. As far as human foresight can accomplish it, the aim is to think the entire problem through to its conclusion. Then, after the U. S. Reclamation Bureau has completed that work, the project is submitted to the Secretary of the Interior and it must not only have his approval, but he must certify to Congress that the project is feasible and will probably return all the money invested. Even there the safeguards do not stop. Before the Secretary's certificate can go to Congress, the project has to be approved by the President.

None of these safeguards were thrown around the previous developments. No such safeguards surround private development at the present time, and they are so complete and are being carried out with such thoroughness that speculation as an influence in any development has been entirely eliminated.

There is another objection to reclamation, which is more potent, and that is the widespread belief in the eastern part of the country that every new farm created in the arid region adds to the surplus and lessens the price of the farms in other parts of the country. It is this belief which has led to so many resolutions by granges and other organizations, against any further reclamation development, and that belief is not confined to the country outside the arid region. It exists there. I know of a little valley which grows a few hundred acres of asparagus. It has a market, high prices, is doing well, feels sure that if there was not another acre of asparagus grown, it would do better. Consequently it passed a resolution against any further reclamation. The people do not realize that the number of asparagus eaters is growing all the time; that there is need for more; that if their policy had been adopted ten years ago, their farms would not have been reclaimed.

The truth is that irrigation development, with the single exception of the fruit area in California, is not keeping pace with the need for its products. In the arid region itself, the cities are growing much faster than the

¹Address presented before a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers, at Kansas City, Mo., December 1929.

²Commissioner of reclamation, U. S. Department of the Interior. Hon. Mem. A.S.A.E.

country, the demand for food products is growing faster than the increase in production, so that to meet the needs of the arid region, reclamation must go on.

Furthermore, every new farm established within the arid region, every new area which is brought under cultivation, means the purchase of new equipment; it means the purchase of material for houses, it means the purchase of clothing; it means a thousand and one things furnished by factories in the East which are operated by people who live in the East and who are fed from eastern farms.

A few days ago, in Chicago, I called attention to the demand for manufactured goods by the irrigated oases of the West. I pointed out that 17 of the 24 reclamation projects in 1928 bought 95,000 carloads of goods, largely manufactured in the East, by workmen who lived in the East and whose food came largely from eastern farms.

The gentleman to whom I made this statement said that, if the half a million people on western reclamation projects had all stopped in Iowa and stayed there, they would have needed just as many clothes and just as many automobiles. I told him that was doubtful. Moreover, if they had stayed in Iowa they would have grown corn, oats, and hay, of which we have a surplus, whereas they are now growing olives, oranges, sugar beets, and long staple cotton, things that the country needs and things which we now have to purchase in part from abroad. Instead of competing with Iowa farmers, they enabled everyone in Iowa to have better food. The idea that the irrigated West is adding or will add to the surplus of staple farm crops is a delusion that a better knowledge of what is taking place will remove.

The crops grown on federal reclamation projects have never exerted an injurious influence on the price of staple farm crops. The area of such crops on the projects is too small. The total project cultivated area is only three-tenths of one per cent of the nation's cultivated area. Shown on a map, these widely scattered areas of reclaimed land are only a series of dots in the billion acres of land in the fifteen arid states. They are still more insignificant when compared with the billion acres of farm land in the whole country. Their value, like that of Robinson Crusoe's goat, is not measured by their size but by the overwhelming need for what they produce.

Furthermore, we have reached the time when all talk about a surplus is destined to cease. An editorial in "The Country Gentleman" for December notes the fact that this year we have no surplus in agriculture, and even if we did, one good rain in the Mississippi Valley does more to increase that surplus than all the products grown on the reclaimed areas of the arid States.

Reclamation's Contribution to National Welfare. Thus far I have endeavored to show you that there is nothing in federal reclamation which warrants your disapproval. I now desire to show what a marvelous contribution it is making to our national comfort and prosperity. Irrigated agriculture is the greatest economic asset of nearly every arid state. Try to visualize the Utah deserts as the Mormon pioneers first saw them, and contrast that dreary prospect with the orchards and gardens which now surround the state's beautiful capital city.

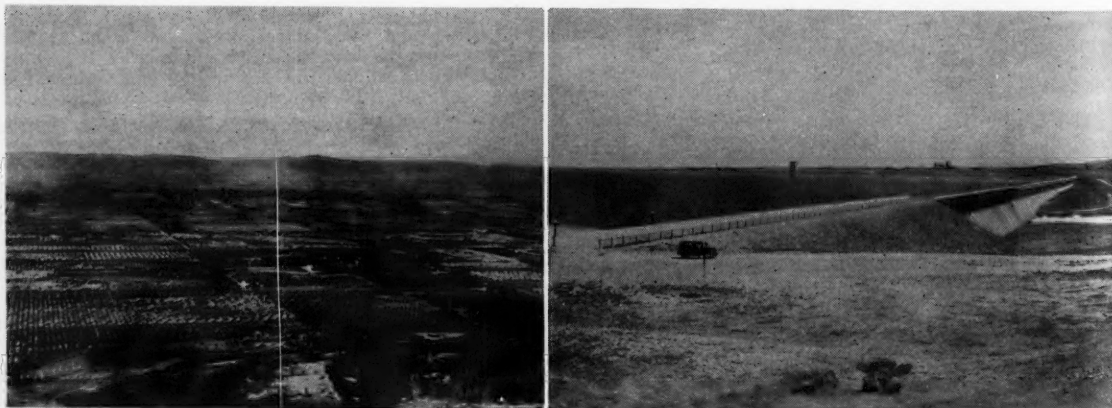
When I first saw the Big Horn Basin in Wyoming, there was an area as large as the state of Massachusetts without a hotel. Its rivers had to be forded and travel was mainly by pack trains. Now it has some of the finest farms in the West, beet sugar factories, creameries, a growing and prosperous agriculture. There is no question as to the value of these reclamation activities or the intense desire of the arid states to have them continued.

Achievements of Federal Reclamation. From the outset reclamation activities have been directed toward (1) creating new communities on unoccupied, unimproved land, public and private; (2) rescuing settlers and homes on uncompleted private development, and (3) conserving the waste waters of rivers and building up a coordinated public and private development in the use of these waters.

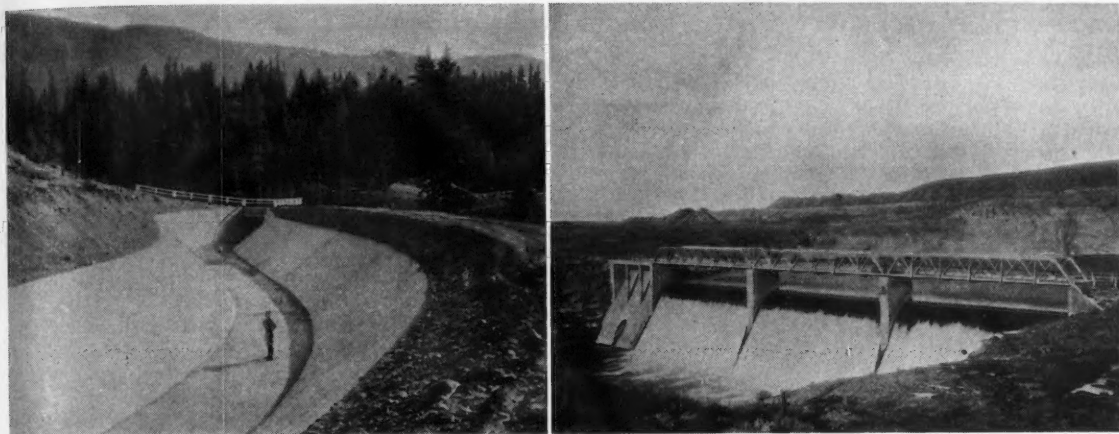
The development of the Big Horn Basin in Wyoming and the Truckee Carson Basin in Nevada are illustrations of the first activity. The project in the Pecos Valley, New Mexico, the work on the Salt Lake Basin project, Utah, are examples of the second activity. The working out of plans for the conservation and control of great rivers like the Colorado and the Yakima are examples of the third activity.

The works already built have cost \$186,000,000. The benefits from much of this expenditure have not yet been realized, because the works are not completed and the farms are not all cultivated, but even in this unfinished condition, the crops grown last year were worth \$143,573,000. When these works are completed and the land all cultivated, the yearly value of the crops will equal the entire cost of the works. No greater national benefits were ever produced by a similar expenditure.

Arizona's Wealth in Irrigation Project. When the federal government took over the reclamation of Salt River Valley, Arizona, the few private enterprises were bankrupt and insolvent and the pioneer settlers were being slowly starved out. Without government aid that section of Arizona would have reverted to the desert. The government spent \$12,744,000 and thereby created farms from which the crops sold last year brought \$26,000,000. Before irrigation began that region was a hideous desert.



(Left) This view shows some of the irrigated farms of the Yakima Valley (Washington) with the fruit trees in bloom. (Right) American Falls dam and reservoir on the Minidoka irrigation project in Idaho



(Left) Intake to the Spexarth Creek siphon, Kittitas main canal, on the Yakima project in Washington. (Right) The Willwood diversion dam on the Shoshone Irrigation project in Wyoming

Now the homes, gardens and beautiful environment cause thousands of people from all over the country to go there for the winter. The cheap local food supply from these farms has been one of the great factors in the development of the copper mines immediately to the east. This project is the mainstay of Arizona's prosperity and of its stable and enduring wealth.

This marvelous transformation has been accomplished without any injury to agriculture in other sections of the country. On the contrary, the East and Middle West have gained. Its farmers buy farm machinery and other manufactured products made by workers fed from eastern farms. The long-staple cotton grown there is needed by our tire makers. Every pound grown there means that much less to be imported from Egypt.

It is one of the centers for the production of citrus fruits and winter vegetables. Thousands of carloads of winter lettuce go from there to eastern cities, but, if not grown there, it would simply mean that the country would have less good food, because it would cost too much if grown in eastern hothouses.

Yakima Valley Transformed. Let us leave the Southwest for the dry Northwest. When the Northern Pacific Railroad was built there was not enough freight in the whole of the Yakima Valley in Washington to pay for the oil used on the locomotives. The cost of transcontinental travel and transportation had to fall on the rest of the country, and that made freight and passenger rates high. There were no farms, there were no towns, the Yakima River ran unused to the sea. Private enterprise sought to bring about its development. A promoter spent his fortune before the canal was completed, and committed suicide. The people on the dry farms under a half-built canal, threatened with ruin, appealed to the federal government, and for twenty years work has gone steadily on, carrying out a coordinated plan for the complete conservation of the water of this river. It means the building of six reservoirs, of which five have been completed. The sum of \$18,350,000 has already been spent on irrigation works. It will be ten years before the work is completed and that will mean a further expenditure of 20 or 25 million dollars.

What has been accomplished? Instead of a desert there are thousands of acres of orchards, the fruit from which goes to practically every country in the world. You can find it in the stores of Australia, India, China, Japan, Germany and Italy. It has a world-wide market because of its superior appearance and quality. It does not compete with the orchards of Iowa, Illinois, or Kansas, but it does add to our export trade and national wealth. The federal government has spent \$4,230,000 on irrigation

works for the Sunnyside division of the project. Last year the crops from this division were valued at nearly \$8,000,000. The irrigation of this valley has created the cities of Yakima, Ellensburg, and half a dozen other smaller cities. The leading cities, with their stores, their fine hotels, their thousands of people, their immense refrigerating plants, are as much the result of irrigation as the dairy herds and the apple and pear orchards. Automobile makers sell thousands of cars. Several of the great chain stores are found here. That has not hurt eastern agriculture. On the contrary, it has helped it. It has not hurt the people who like good food and more of it. On the contrary, it has made a great contribution to their needs and desires.

Desert Converted Into Gardens. Before the federal government started reclamation in the North Platte Valley, it was an unpeopled sagebrush desert, with jack-rabbits and coyotes the principal inhabitants. Last year one town in that irrigated area paid one railroad \$800,000 for freight shipments.

Before government irrigation started on the Snake River and the Boise River in Idaho that state had to depend on mining and stockraising. It had few people and little wealth. Now the freight paid each year by the irrigation districts along Snake River amounts to more than all of the yearly freight payments to the railroads by the entire state, before these projects were begun.

I could extend this recital to other federal reclamation projects. In nearly one-third of our national area it has created on what was once dreary, worthless deserts, an agricultural, economic and social life, equal to that where lands are watered by rain. It has given the nation more kinds of food and better quality than can be grown elsewhere in this country or be purchased abroad. It has given pioneers a chance to make homes for themselves and families. It has been the greatest experiment station and demonstration farm in our national history.

A Conservative Reclamation Program. So far as the justification of reclamation activities is concerned, we can say with Webster that the past is secure. Now let us consider what is going on at present. Let us see what sort of speculation and promotion is behind the work which the Bureau is now doing.

The disappointing feature of our activities is that we are doing so little compared to what the West needs. People living on farms that lack water appeal to us to save them and are often bitter when we can not respond. What we do now depends largely on the success of what has been done in the past. We can only spend each

year the money that year by year comes into the reclamation fund. The main part is the payments for water from users on the older projects. It amounts to eight or nine million dollars a year. That has to meet the development needs of one-third of the nation. All of it is now being spent on a ten-year program designed to complete projects begun in the past. It does not go far because we can not rely on the natural flow of streams. New development has to be based on storage which is costly.

An adequate review of what is being done is not possible. Only a few examples can be given. We will begin with one of the largest and costliest enterprises of the ten-year program, the Kittitas division of the Yakima project in Washington. That division is to cost \$11,000,000. We are now building canals to water 70,000 acres of land at a cost of \$160 an acre. Why are we doing it? The answer is that the soil and climate of that valley give exceptional returns from irrigated farms. The water of this river ought therefore to be conserved. Doing this will make a large increase in our national wealth.

We are doing it in part to save the homes of heroic pioneers who went there when irrigation was new. They settled on small tributary streams which they thought would furnish ample water. Experience has shown they will not. There must be a supplemental water supply or these people must move out. They know what water is worth. They are contracting to pay the full construction cost. To make sure that there would be no speculation, all this land has been appraised by expert valuers, and the owners have agreed, if they do sell, to sell at this appraisal value. Some of that land is in a railroad grant. It is being sold to settlers at the appraised price, which in many cases is \$2.50 an acre, or less than the company has paid the state in taxes.

A very difficult and costly canal is being constructed in Idaho. It has to go for fifty miles across a lava bed. Why is that being done? Is this the work of a promoter or speculator? Far from it. This canal is being built to save homes, orchards, farms and towns already established. The labor, money, privation and heroism which went into their creation are all endangered by an uncertain water supply. Over on Snake River water is running to the ocean unused. These farmers could not build the canal needed to bring a dependable, ample supply of water to their doors, but they can pay the government for doing it. That canal is a rescue agency like the engine that puts out a fire. The crop lost two years ago was worth almost as much as this canal will cost. These improved farms are obligated to pay for that water and will pay for it. How anyone, East or West, could question the wisdom of such a sound business and beneficent activity is more than I can conceive, and no one would question it if he knew the facts.

The Owyhee project in Oregon and Idaho is the costliest project yet undertaken by the government. Eighteen million dollars will be spent on the storage works to regulate the flow of Owyhee River and build the tunnels and canals to carry the water to 70,000 acres of exceptionally fertile sagebrush desert, and to the homes and fields on 50,000 acres which have only a partial water supply. They can not survive without it. The national loss and economic injustice of doing nothing are so apparent that Congress has supported, without division, the Department of the Interior's recommendation of this work.

Boulder Dam. I would like to go on with this recital and furnish instance on instance to show how fully reclamation is entitled to the admiration and support of this society. I surmise that its misconception has grown in part out of the controversy over Boulder Dam, and the talk of one million acres of land to be brought under cultivation, but if there is any activity in this country which is not speculative, if there is anything which is being done by public or private effort in response to an imperative public need, it is the great dam which is to control the Colorado River. That river as it is now is of

little value. When in flood it is a turbulent, dangerous stream, and when the snows are melted, it shrinks to a shadow of its former size and has very little value for irrigation. It needs regulation, beyond all other rivers, because at the mouth it flows on the rim of a basin and down below it, in southern California, is the Imperial Valley with 60,000 people and \$100,000,000 worth of property menaced by its floods. Following these floods, drouths often menace the rewards of the farmers who grow crops which can not be produced elsewhere and which the country needs.

All of us are better off because of the thousands of carloads of early lettuce that come out of the valley, and the other thousands of carloads of cantaloupes which we are all glad to get and better off for getting. They come at a season of the year when they can not be produced elsewhere.

Boulder Dam was started to save Imperial Valley, but in the eight years in which it has been under discussion, the factories, the homes, the population, the commerce of the coast counties of California, which include the cities of Los Angeles and San Diego and a score of other important cities, have been growing at a marvelous rate. They have now reached a point where the demands for water are greater than can be supplied by the rains that fall on their foothills. If they are to continue to grow, if the present prosperity is to be maintained, they must have water from the Colorado River, and that water can not be drawn from an unregulated stream.

The original idea was to pay for the dam, in large part, out of the federal treasury and make the farmers of Iowa and Illinois contribute, as they do toward flood protection on the Mississippi River, but the industrial development has made a market for power, and the water released for the farms and towns can be made to generate power in being released. This means an industrial development which will create a demand for far more food than the irrigated area under this project will supply. It is no menace to the agriculture of the rest of the country. It is no burden on the taxpayers of the rest of the country, and opposition to it by anyone is based on a lack of knowledge of the facts.

Other Proposed Developments. There are other great developments proposed which have size and cost that place them outside the income of the reclamation act. Most of these are on the great rivers of the Pacific slope. Columbia Basin is the largest. It is so monumental in size and cost and in the agriculture that it will create, that it needs an economic as well as engineering plan. That will be worked out just as it has, by years of study, been worked out on the Colorado. In the meantime other sections need not worry about its competition. This century is to see a marvelous development of commerce and industry on the Pacific. It will need all these farms will produce long before these homes and farms can be created.

Drainage Cheaper Than Farming Wet Spots

AN AREA in the field too wet to farm does more than waste the spot of land which it covers. Such irregularities also waste the time and money of the farm operator because he must plant around them, cultivate around them and harvest around them. One Iowa farmer found that he could plant corn with a two-row planter at the rate of nearly two acres an hour in a large rectangular field of approximately 100 acres while his rate of planting in a triangular field of 19 acres was only 1.2 acres per hour.

Enlarging fields and eliminating irregularities do much to increase the efficiency with which farm equipment can be used. Sometimes this rearrangement requires pulling of stumps, filling of surface ditches and draining of low spots in the field.

The Engineering Factor in Reclamation¹

By W. G. Kaiser²

President, American Society of Agricultural Engineers

IN ALL the activities of the American Society of Agricultural Engineers there is no work of greater value than that which confronts the Land Reclamation Division. To men like yourselves, who are in close contact with the Division's activities, I feel confident that I can make this assertion not only without fear of contradiction but with your full approval. Among the uninformed or misinformed, however, who are inclined to associate land reclamation with the opening up of new land for cultivation and thereby further aggravating a condition of overproduction, it must be admitted that there is considerable opposition to several phases of reclamation.

In times of surplus production, such as have been experienced in recent years, would-be champions of the farmer are prone to attach the blame for this situation to the slightly increased acreage brought into cultivation through the opening up of new projects of reclamation in drainage and irrigation. Because of this and because of gross mismanagement in the financing and the settlement of some irrigation projects, reclamation in general has been subjected to a great deal of criticism and consequently has received much unfavorable publicity.

A glaring example of this kind of publicity appeared in an editorial in the Chicago "Tribune" on December 8, 1929. This editorial, entitled "The Reclamation Racket," compliments the Tribune's Washington bureau for exposing the shortcomings of certain irrigation projects which, it says, were omitted by the Commissioner of Reclamation in his report to the Department of the Interior.

The complete editorial is on file, but I will read only the last paragraph which is particularly caustic in condemning reclamation. It says: "Reclamation in the United States has been a huge financial racket. It might even be said that the more successful the reclamation undertaking the greater its injustice and inutility. These unproductive western lands are brought under cultivation at the expense of the great majority of the taxpayers for

exploitation, often enough by nomads and land sharks. Furthermore, the agricultural products of the new land are in competition with the farm products from our already too great arable land. It is an aggravation of the farm problem and the farmers are helping to pay for it. Only when the farms of the United States fail to meet the requirements of the consumer will the cultivation of arid land be justified and that is a distant prospect."

It is extremely unfortunate and decidedly unfair that reclamation should be characterized as a "huge financial racket." Although such denouncements allude to mismanaged projects, all the various phases of reclamation suffer more or less as a consequence. In the minds of many we find ourselves regarded as a kind of "racketeer." Here is a situation that needs to be straightened out in order that the great work which is being done by reclamation engineers in meeting present day emergencies will receive proper recognition.

Soil Erosion. Soil erosion control is an engineering problem of the greatest importance. Any doubt as to the need for adopting measures to control soil erosion is and should be immediately dispelled by the facts on soil wastage which are presented in Circular No. 33 issued by the U. S. Department of Agriculture, entitled "Soil Erosion a National Menace." This was written by H. H. Bennett of the Bureau of Chemistry and Soils and W. R. Chapline of the Forest Service.

Although you are familiar with the contents of this excellent publication, I am asking you to bear with me while I read several paragraphs which point out the gravity of the soil erosion menace which faces our agricultural people and the nation:

"The amount of plant food in this minimum estimate of soil wastage by erosion (1,500,000,000 tons of solid matter annually) amounts to about 126,000,000,000 pounds, on the basis of the average composition of the soils of the country as computed from chemical analyses of 389 samples of surface soil collected by the Bureau of Soils. This is more than twenty-one times the annual net loss due to crops removed (5,900,000,000 pounds according to the National Industrial Conference Board). The amount of phosphoric acid, nitrogen, and potash alone in this annual-ly removed soil material equals 54,000,000,000 pounds.



An example of the ravages of soil erosion—not a rare sight in most any section of the country—which might have been prevented by timely terracing and soil and cropping treatment

¹Address presented before a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers, at Kansas City, Mo., December 1929.

²Agricultural engineer, Portland Cement Association. Mem. A.S.A.E.

"In many instances the farmer does not know just what to do to slow down erosion. In many other cases he does not even suspect that the waning productivity of his fields results from any cause other than a natural reduction of the plant food supply by the crops removed. He does not recognize the fact that gradual erosion, working increasingly and more or less equally at all points, is the principal thief of the fertility of his soil until spots of subsoil clay or rock begin to appear over the sloping areas."

So slow and gradual is the process of land wastage by erosion that farms are literally washing away under the farmers' feet often without their knowledge. Something must be done to warn our farmers of this threatening disaster. The whole proposition of controlling soil erosion is one of national concern. Its solution should not be left to the individual land owners, because they will not know how to cope with the situation and will not realize the seriousness of their erosion losses until diminishing crop returns indicate that something is amiss.

It may require some action like that taken by the Federal Land Bank of Houston to bring home to our people the importance of controlling soil wastage. This financial institution, for its own protection, insists that borrowers terrace all rolling lands to insure the permanency of soil fertility during the terms of the loans. For a number of years this bank has been carrying on a broad program of soil conservation in cooperation with the Texas A. & M. College and other institutions. The Federal Land Bank of New Orleans also requires that all rolling lands, on which it loans funds, must be terraced. The principle back of this procedure is so economically sound that it is quite probable that insurance companies and other large institutions which are heavily interested in farm loans will soon adopt similar practices.

That the soil erosion problem is receiving an increasing amount of attention is evidenced by the fact that the Extension Division of the Oklahoma A. & M. College with the cooperation of the "Oklahoma Farmer-Stockman" recently called a meeting of soil specialists, agricultural engineers and others to consider the question of soil erosion and its control. Governor William J. Holloway of that state took a leading part in this soil conservation conference as the meeting was called and sent out invitations urging attendance. This meeting has done much to place the soil erosion question before the people of Oklahoma in a way that the seriousness of the problem cannot be questioned. The extension divisions and the governors of our other agricultural states might well emulate the example of the Oklahoma authorities.

The actual control of erosion, whether it be of the gully washing or sheet wastage type, is an engineering matter. The successful construction of terraces for controlling sheet erosion involves the consideration of a number of engineering factors depending upon the slope and the soil type. In Circular 33 of the U. S. Department of Agriculture appears this statement: "If the protection embankment is given too much or too little slope, there is danger of breaks and intensified washing that may exceed that prevailing before the terrace was constructed."

This danger is pointed out in Circular No. 218, entitled "Terracing in Oklahoma" and written by G. E. Martin of the Oklahoma A. & M. College. He writes: "A half-finished job of terracing is likely to result in wasted time, wasted effort, and wasted soil, and tends to bring into disrepute the most satisfactory means, so far determined, of preventing the enormous annual loss of soil fertility which now occurs."

"The importance of measuring the slope to determine the proper spacing of terraces can hardly be overemphasized. Too heavy a grade or too much fall along the terrace line can defeat the moisture conservation objective and may result in hillside ditches instead of terraces."

A great deal of research work is yet to be done before we can be certain of the most economical and most effective



An irrigated orange grove on the Salt River Irrigation project in Arizona

method of controlling soil erosion. At the annual meeting of this Society at Dallas, Texas, in June of this year, C. E. Ramser, senior drainage engineer of the U. S. Department of Agriculture, outlined a number of investigations that were being conducted by several of the bureaus of the Department in which the Division of Agricultural Engineering is cooperating primarily with reference to the engineering phases of the studies. It is well to call attention to several of the studies which he lists because of the engineering factors involved. These studies have for their objective the determination of:

1. The effect of vertical and horizontal interval between terraces upon the run-off and rate of erosion
2. The effect of grade terraces upon the rate of soil erosion
3. The maximum permissible length of terraces with uniform or variable grade on different slopes and soils
4. Means of preventing erosion at the ends of terraces
5. The effect of terraces on farm operations and upon modern farm machinery when used parallel to and across terraces
6. The most efficient and most economical terrace for each principal soil type
7. The conditions under which various types of soil-saving dams built of different materials are most effective
8. The most economical methods of constructing terraces and soil-saving dams with different types of equipment, more effective methods of construction and more efficient equipment
9. The most effective way of maintaining terraces and soil-saving dams and other devices for preventing soil erosion.

In the matter of soil conservation the reclamation engineer must assume a very heavy responsibility. Not only must he provide the latest technical information on soil control measures under a great variety of conditions, but he must also initiate action in sounding the alarm relative to the dangers of erosion.

There is scarcely a section of the United States that can afford to overlook this insidious soil-wastage problem which is slowly eating away our fertile top soils. Not content with robbing us of our soil fertility, it is also increasing flood hazards by removing the surface soils that are moisture retaining and thus increasing the amount of run-off of rain water which in many sections the crops can ill afford to lose.

The question of soil conservation is one of such vast magnitude and has so many ramifications that every possible agency should be aroused to action. In this connection it would be highly appropriate and most oppor-

tune for this group to petition the Secretary of Agriculture to appoint a reclamation engineer to contact the various state colleges and coordinate and stimulate research and extension activity with reference to control of soil erosion and other phases of land reclamation. Furthermore, it would seem well within the province of this division to take such steps as may be deemed expedient to initiate action on the part of state and federal agencies. Here is a national problem which challenges the best efforts which this group can put forth.

In this connection the Land Reclamation Division might well sponsor a National Soil Conservation Congress. With proper handling I believe that such a conference would be of inestimable value to the farmers of our country. This Division is the logical group for sponsoring such a meeting and all indications point to the present as the opportune moment for getting the work underway.

Drainage. Under the present economic conditions it is generally recognized that activities in the drainage field should be limited to lands under cultivation and to the maintenance of existing improvements. The efficiency of many drainage lines, especially open channels, has been seriously reduced by neglect or lack of proper or adequate maintenance. Lack of attention to regular maintenance such as the removal of sediment, debris, plant growth and other materials that reduce the amount of flow means in most cases that the system will not function effectively with consequent economic loss to those who till the supposedly drained areas. Likewise the professional standing of the engineer who designed the system is likely to suffer. Therefore every drainage engineer should make it his solemn obligation to advise his clients of the maintenance problems which will have to be met and should make recommendations for handling them.

The economic maintenance of drainage ditches presents engineering problems of equal or greater importance than the original survey and construction of the system. Here is a broad field for reclamation engineering which is not generally appreciated.

Irrigation. As in the case of drainage, the logical activities of the reclamation engineer in the irrigation field is largely in the maintenance and improvement of existing structures. In irrigation as in drainage projects, there have been flagrant cases of gross mismanagement which have cast a stigma of general unpopularity over this branch of reclamation. This is a discouraging situation and makes the job of the irrigation engineer all the more difficult. Despite this situation, the work of the irrigation engineer is indispensable. It is his task to find the most economical way to maintain existing structures and conserve the millions of dollars invested in irrigation projects.



Irrigation ditches under construction in a prune orchard in California

He is obligated to devise the most economical method of distributing water. From the time the water leaves the source of supply until it is applied to the growing crops, there is a series of engineering factors involved, any of which might have serious effect on the success or failure of the project.

That there have been failures in the irrigation field was inevitable. Had there been the proper set-up, that is, the proper balance of economic and engineering factors, it is certain that the number of failures would have been greatly reduced. As agricultural engineers interested in this phase of our profession, we should see to it that the economic as well as the engineering sides are given proper emphasis when irrigation projects are organized, designed and constructed. Projects which preliminary surveys disclose to be economically unsound should not be recommended regardless of how attractive the engineering phases of the project may appear.

Another important field for the irrigation engineer is in the rehabilitation of lands in receivership, especially those projects which are basically sound but which due to mismanagement or other causes have defaulted in their payments. This applies likewise to the rehabilitation of drainage districts which, though in desperate financial straits, could be made profitable by the proper set-up.

Land Utilization. In the land utilization phase of reclamation, the soil erosion engineer, the land clearing engineer and the drainage engineer must often work closely together. Here is a field of endeavor which is also engaging the attention of farm power and machinery engineers in fitting the fields for the more efficient operation of large machines. There are countless fields all over the country which are small and irregular in shape. The cost of production on such fields is high because they do not lend themselves to the operation of labor-saving machinery. Some of these fields are bound by stone walls or hedges which have been there since the time when hand methods of farming were in vogue and small irregular patches were less objectionable from the standpoint of efficient utilization. Other fields owe their irregular form to undrained areas or to patches of uncleared stumps or trees or to ditches which, though relatively small, are impassable to farm machines. All of these natural barriers occupy space which is unproductive and increases the overhead charges which must be carried by the areas under cultivation. The rearrangement and enlargement of the fields by the removal of stump patches, stone walls, hedges, the draining of wet spots and the tiling and filling of ditches is the work of the land reclamation engineer. His activities in this connection go much farther than the removal of physical barriers. They should be preceded by a complete preliminary study of the proposed work to ascertain its soundness from an economic standpoint.

There can be no question as to the importance of the work of the Land Reclamation Division in the American Society of Agricultural Engineers. Its field of usefulness in our Society is second to none, and I am confident that the work which you represent will receive an increasing amount of national recognition. Your decision to hold this mid-year meeting is proof that you are aware of the changing situation in land reclamation work. I am certain that you also recognize the need for making a meeting of this kind an annual event, perhaps convening at some more western point in another year, to give more attention to irrigation and the drainage of irrigated lands.

The Society is deeply interested in all matters relating to land reclamation and regards it, along with structures and power and machinery, as one of its major activities. Just as an engineering society is as strong as its membership, the effectiveness of a division is measured by the aggressiveness and leadership of its members. Land reclamation offers a field of limitless possibilities, and I want to congratulate you on the progressive step you have taken in calling this meeting and organizing to make this one of the strongest units of our Society.

Late Developments in Preventing Erosion¹

By J. T. Copeland²

THE developments set forth in this paper are supplementary to the findings presented by the author in 1921 and to all subsequent soil erosion reports offered before the American Society of Agricultural Engineers. The principles herein presented are authenticated only by the author's field observation and experience in solving soil erosion problems with the farmers and county agricultural agents of Mississippi since 1919. From these field developments comes a method of soil erosion control which is being called Copeland's Natural Principle Terracing System.

The natural principle terracing system was discovered through a study of faulty terracing practices and the endeavor to solve these errors by following the usual tendency of water in its behavior with soil. The most conspicuous and immediate fault of most terraces was the falling of soil fertility where the land was apparently properly terraced. A study of this condition revealed that the terraces were given either a soil-carrying or scouring grade, such grades being necessary to insure carrying capacity of the terraces as located. The arbitrary locating of terraces as based upon acreage, latitude, gradations of topography, rule of thumb, or caprice of mind had placed the terraces so at random that it was necessary to give the terrace grade too much pitch. The apparent correction was a terrace with a soil-saving grade, located to intercept surface water at sufficiently frequent intervals in order that soil movement would not occur. This conclusion put into practice disclosed the phenomenon that soils have natural planes of erosion which are altitudinally uniform under conditions of similar soil type and cultural practices. Therefore, terrace lines at regular elevations may be located to intercept all normal soil wasting by arresting its movement at the soil erosion plane—paths, turnrows, old terraces, old fence rows, old building sites, etc., excepted. Later developments disclose further that the plane or belt of erosion is inclined in direction from the water divide of the slope, ridge or hill toward the natural terrace outlet, the nearest upper drainage of the area.

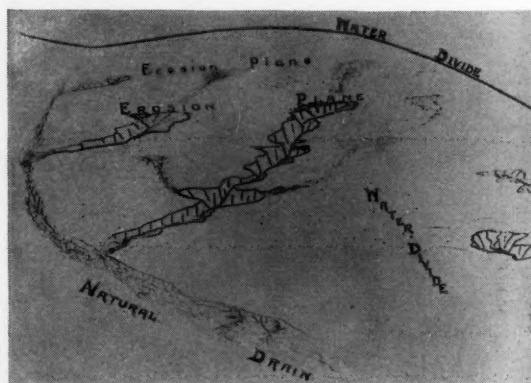
The difference in elevation between adjacent planes of erosion is influenced by soil type, water-retaining capacity of soil, cultural practices, and the organic content of the soil, the organic content with its water-retaining ability bearing the greatest influence upon frequency of erosion. Because of the increased weathering as influenced by the desiccating effect of the sun, the southern exposure of a given soil type under similar cropping conditions as compared to the northern exposure of the same type under identically the same cultural practices is found to erode and waste away in more numerous planes, the increased planes occurring in numerical divisions. In Mississippi under average field conditions of clean annual cultivation, the elevation between erosion planes varies from one foot in the sandy south coastal plain area to three feet in the clay northeastern highland area.

Terrace location by Copeland's Natural Principle Terracing System is determined by finding the difference in elevation of adjacent erosion planes and establishing that difference as the measure for locating terrace elevation for the area. As soil type, cultural practices, and organic content change, the measure likewise should change, if the symptoms of erosion indicate soil movement sufficient to laden the lower adjacent terrace dangerously. Sheet

erosion usually occurs most pronounced in sandy soils and permits less interval between terraces than does the gully erosion of stiff clays. An abrupt slope quite often reveals an altitudinal alternating of major and minor erosions. Terraces can be located using major erosions as indices and this practice is recommended for meadow or pasture lands. On soils with both sand and clay content, it is usually advisable to follow gullying as the index for terrace location, depending upon contoured crop rows to arrest the sheet erosion of the sand. In Mississippi it is generally recognized that crop rows and cultivation must be contoured to effect adequate soil erosion control and that lands having upward of fifteen per cent slope are too abrupt for economical cultivation. The Yazoo and Mississippi Delta area having been reclaimed by drainage and levee systems is largely exempt from erosion losses, but the more undulating sections of this area are resorting to terraces to sustain the fertile alluvial soil.

Terrace grade by the natural principle terracing system is forecast by the terrace altitudinal location, the integral altitudinal foot indicating the integral inch grade per one hundred linear feet of terrace. For example, a two-foot difference in erosion plane elevation indicates a two-inch depositing grade for terraces for the area. Formerly in Mississippi terrace grade was a matter of conjecture, but soil losses resulting therefrom forced a change of practice and a study for improvement, many farmers using level terraces in order that the greatest possible amount of soil might be saved. However, the correct grade was assumed to be that which would remove surface water and at the same time retain all except soil in suspension. To that end, grades of contoured crop rows were studied for desirable deposit and the second phenomenon of the system was discovered, namely, the coincidence of terrace location and grade. Furthermore, the grade of the terrace thus established matches the incline of the erosion plane in its slope from the water divide to the natural drain.

In use the natural principle terracing system has established the fundamentals of terrace success and has simplified the whole field practice until it has become a matter of following a routine of simple technique which is readily effective with both farmers and boys. Neither apology nor premise is assumed for the lack of coordination between this system and any prevailing hypothesis. Until sufficient research and analyses are performed to substantiate the field findings, it is impossible to either explain or assign cause by any of the known laws.



This diagram illustrates the natural principle of soil erosion

¹Paper presented at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers at Kansas City, Mo., December 1929.

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The Use of Supplemental Water¹

By J. C. Russel²

IN THE very heart of the Great Plains in central Nebraska there lie 450,000 acres of land in one continuous tract, flat as a table, sloping eastward 6 to 8 feet to the mile, of loess soil 100 feet deep, adequately drained, and of potentially high productive quality, traversed by highways and rails, occupied for many years by a stable population of farmers and townsmen and supporting well-organized agricultural activities on rainfall alone.

It is not an arid section. It is not even marginal dry-farming land. It is a region of corn and wheat fields, four acres of corn for every three acres of wheat, and eight acres in corn and wheat out of every ten. In its virgin condition it was covered with little blue stem. Its average annual rainfall over a long period of years has been about 24 inches. It is a region where county corn yields are occasionally as high as 40 bushels and wheat as high as 25 bushels. But it is a region of uncertainties.

In 1913 corn yielded 2.0 bushels per acre and wheat 9.6 bushels. In 1926 corn yielded 5 bushels per acre, and wheat 5.3 bushels. One-third of the time the yield of corn is under 15 bushels and the yield of wheat is under 8.5 bushels.

It is a region of fitful drouth. In 23 years in the western third of this area there have been 65 occasions averaging 48 days in length, between April 1 and October 31, when not more than one inch of effective rain has fallen. In 1922 the western third of this area went 109 days with only one rain of over $\frac{1}{2}$ inch.

Flowing by this region on the north, a few miles away in a deeply cut valley, is the Platte River carrying enough water at seasons, if stored, to supply these 450,000 acres with better than 12 inches of water over all.

Some 15 years ago a group of citizens actuated by the drouth disaster of 1913 sponsored a movement to divert the waters of the Platte in seasons of flood, and store them in the retentive loess subsoil against periods of drouth. Their idea was not to irrigate, in the accepted sense of the word, but to supplement rainfall. They called it supplemental irrigation.

It is not the purpose of this paper to explain the proposed Tri-County Supplemental Project of central Nebraska. It shall be referred to from time to time as illustrative material with which the writer is familiar. The real purpose of this paper is to discuss the philosophy, theory, and practice of supplemental irrigation.

Supplemental irrigation has been defined as the practice of artificially supplying to the soil sufficient water to carry crops through periods of drouth and to make up the difference between the crop requirements and rainfall in seasons when rainfall alone is inadequate. It is irrigation in regions where rainfall contributes a substantial but indefinite portion of the crop's water requirements. It is a comparatively new idea. Is it necessary? Will it work? How should it be done?

First, is it necessary?

Perhaps it seems strange that a section like Adams, Kearney and Phelps Counties in central Nebraska should be brought under cultivation, become completely settled, develop a complex but stabilized agriculture, and thriving cities and towns, and then after 40 or 50 years the complaint be voiced that rainfall alone is inadequate, and supplemental irrigation is required.

Perhaps you think that the complaint against inadequate rainfall is a fancied one, and will cease to be heard when the national agricultural situation is alleviated.

Perhaps you are one who feels that as a general principle it is economically and socially unsound to project irrigation eastward into stabilized non-irrigation farming regions when land awaits colonization in existing government reclamation projects, or when thousands of acres of humid country could be reclaimed by drainage or terrace construction.

I assert that the complaint of central Nebraska against inadequate water, coming at this stage of agricultural development, is inevitable and that it marks the beginning of a problem of reclamation in portions of the Great Plains as important in national welfare as the comprehensive irrigation developments in arid territory.

I have three reasons for making this assertion.

First, the Great Plains country was settled in a pioneer stage of national development by peoples who willed to withstand its rigors, who put what they won from it back into it, and who thereby created national wealth just as in all other sections of the country. But the pioneer spirit no longer exists. The nation is in a new stage of development. Those who possess the land now find that it is overevaluated. And in the Great Plains its value must either decline, which would be a national calamity, or its value must be stabilized by mitigation of the hazard of drouth.

Second, the newness of the land has worn off and its fertility has declined, and its earning power has been impaired. We know now what we did not know in the beginning, or even 20 years ago, namely, that it is not possible to maintain fertility without irrigation in a region that is subject to frequent drouth.

This statement may call for additional explanation. In Adams, Kearney, and Phelps Counties, Nebraska, which are illustrative of a condition which extends southward across Kansas and northward into South Dakota, there are only 4.6 acres of legumes today for every 100 acres of land under cultivation and the acreage is declining. It is hazardous and uneconomical to grow them, hazardous because crops "burn up" more quickly on legume land, and uneconomical because legumes are heavy users of water and rainfall alone is insufficient for satisfactory tonnage.

Because there are no legumes there is no cattle feeding and therefore no manure. Unless it should transpire that nitrogen fertilizers can be used to advantage, and this is highly problematic, there is no way known to maintain the soil at the high productive level of its early years, without supplementary rainfall.

The third reason for my assertion that the complaint of inadequate water in the Great Plains is an inevitable one is that the efficiency of precipitation is growing less. It is growing less for the reason that the silty soil of central Kansas, Nebraska, and Dakota is losing or has already lost its virgin porous structure, and is less receptive of rains than it formerly was, and forms an inferior natural or artificial mulch and loses water more rapidly. Also as a result of the decline in fertility it probably takes more water to produce a pound of dry matter.

I am discussing the question, is supplemental irrigation necessary? I have put it on its larger philosophical basis. Let us look for a moment at actual conditions of moisture deficiency and see if it is true that rainfall is insufficient. Let me refer again to Adams, Kearney and Phelps Counties, Nebraska.

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The average yield of corn in these counties for the last 25 years is 21.3 bushels, and the average for wheat is 14.3 bushels. With corn at 60 cents per bushel and wheat at 90 cents, a landlord's gross income from 4 acres of corn and 3 of wheat is \$4.25 per acre. Does such an income justify a valuation of \$75 to \$90 per acre on farm land.

Let me pause to say that I am not knocking land values in my state, or in any other state, for they are out of proportion to their rental income in many sections. I am trying to make a claim for supplemental irrigation as a means of stabilizing existing evaluations in a region where such a means of stabilization seems possible.

Corn yields in the three mentioned Nebraska counties have exceeded 32 bushels as a county average only about one year in five. About half the time they are less than 24 bushels per acre. Wheat yields have been satisfactorily high—over 20 bushels—only about one year in six, and unsatisfactorily low—less than 12 bushels—one year in three.

Anyone who studies precipitation records year by year in connection with yields is led to the indisputable conclusion that the direct cause of these low yields is a shortage of moisture.

Before we leave the question of whether or not supplemental irrigation is necessary, let us ask whether there is any possible substitute. As I see it, for the Great Plains section with which I am familiar there is no substitute for supplemental irrigation on any lands where it is possible to use irrigation.

We come now to the second major issue of this paper. Will supplemental irrigation work? As I see it, the answer can only be very indefinite. It depends upon the character of the project, whether water is supplied by pumps at or just preceding critical periods of drought, or from flood water storage available for application in fall and early spring. It also depends upon the crops grown, the intelligence and foresight of the farmer, and all of the other factors which ordinarily affect the performance of irrigation water.

In the Tri-County Project it is contemplated that flood-storage water to the amount of one acre-foot for each of 450,000 acres will be available for subsoil storage either in fall or spring, and some additional water during July and August. It has been shown by saturation plot tests in the field that 2 to 2½ inches of water available to plants can be stored in each foot of subsoil. It is possible to store in the upper six feet of soil, within the reach of corn and wheat roots, one acre-foot of irrigation water.

What can we reasonably expect this water to do, not in occasional years, but as a long-time practical average? Nobody knows positively for the reason that no supplemental irrigation aside from pumping has been conducted under corresponding climatic conditions anywhere, and pump irrigation is not comparable for it is done in July and August in dry years only.

In the absence of direct observational data a fairly reliable estimate can be made from an analysis of county crop yields and precipitation data over a long period of years.

A study of such data for the Tri-County Project shows that for each inch of effective rain coming during the pre-season and seasonal months up to July, the yield of corn has been increased 3 bushels per acre, or 36 bushels per acre-foot. Allowing that supplemental irrigation is used consistently each year, and that rainfall alone is fully adequate about one-half the time, we still have an estimate of about 20 bushels of corn as an average annual increase per acre-foot.

In the case of wheat the estimate of what fall irrigation will do has been set at 10 bushels per acre-foot as an average for its consistent use.

In making these estimates, no account has been taken

of what can be produced by supplemental irrigation through the increased fertility practices which will be possible with more water.

The strongest objection to supplemental irrigation, whether it be subsoil storage in fall or spring, or summer irrigation from ditch or well, is that the water will not be consistently used. In wet years the canals will not be kept up. In wet seasons the laterals will not be provided for, and when dry years or drouths come water will not be available at the proper time. After a few years the whole system will be in such disrepute that it will be abandoned. Those who maintain these views insist that it is hard enough to get farmers to irrigate correctly in arid sections, and extension of irrigation into the subhumid territory will only be a more aggravated case.

The Nebraska farmers who practice pump irrigation in our region of 20 to 24 inches of rainfall have shown commendable consistency I think in their use of water. Perhaps it is due in part to the newness of pump irrigation and the vividness with which the farmers recall their recent losses from drouth. In large part, however, it is certainly due to the dependability, intelligence, and financial soundness of those who have taken up with irrigation. In many cases where water has not been used as it should, it is due either to ignorance, which can be corrected, or to costliness of operation.

There is yet one element in the projection of irrigation into subhumid territory that must be taken into consideration, and that is, what shall be grown?

I shall not consider the possibility of the supplemental project going into competition with other already established projects in the growing of products not indigenous to the area as a non-irrigation unit. I am not so concerned whether the supplemental project will grow sugar beets and potatoes, and other crops of high acre return, as I am over the question whether it can if it wants to. One of the elements of soundness in an irrigation project is the possibilities of growing crops of high acre value, and conversely.

There are climatic limitations in the extension of sugar beet and potato culture into the lower altitude of the subhumid plains. How serious they are deserves consideration.

The third question—How shall supplemental irrigation be practiced?—involves many details of culture and engineering that are beyond the scope of this paper. The single point to be stressed is the importance of building the supplemental irrigation program around that system of agriculture which will lend itself most surely to consistent usage of water.

I want to mention again the proposed Tri-County Project in Nebraska. It has been used for illustration in this paper repeatedly because it contains many unusual elements, and it has yet another unusual feature. This feature was unperceived by any of us when the project was under investigation in 1923, and has only recently come to light.

The subsoil of this level area is loess to 100 or more feet deep. And below six feet or so it is dry all the way down as far as we know. At least it is dry as far down as alfalfa roots can ordinarily penetrate. In eastern Nebraska the subsoil is moist down as far as alfalfa roots can possibly penetrate and lift water. At Lincoln, Nebraska, that depth is about 35 feet. In a six or seven-year period alfalfa may exhaust the subsoil moisture to the very lower limit of availability to a depth of 35 feet. It is that subsoil moisture coupled with the 25 to 32-inch precipitation which makes possible the growth of high tonnage alfalfa in eastern Nebraska, and makes that crop desired by farmers. It is this deep glacial and loessial subsoil filled to capacity with water, that has contributed largely to Nebraska being second in the union in alfalfa production, being exceeded only by irrigated California.

At Lincoln in 1924 on normal rainfall in the third year of the life of a good field of alfalfa the state agricultural

college obtained 7.18 tons of cured hay per acre, without any irrigation or fertilizer. During the second, third, and fourth years of that field, it averaged 5.6 tons per acre on normal precipitation. The succeeding two years it averaged 2.0 tons per acre because it had by that time exhausted the subsoil water.

The significance of subsoil water for alfalfa can be stressed by some other data. For five years we have had alfalfa at Lincoln growing in plots practically side by side, one having its natural supply of subsoil water, the other having all subsoil water exhausted by previous cropping to alfalfa. Here are the differences in yields year by year between the two plots in tons of cured hay per acre: 1.40, 1.70, 1.90, 1.89, 3.05, average 2.00 tons.

Now we found this alarming thing, namely, under the precipitation and runoff conditions and grain-cropping practices that obtain over a large portion of eastern Nebraska, after alfalfa has been grown on land once, it takes years and years, in cases perhaps hundreds of years, to restore the virgin supply of subsoil water, and we are wondering where we are going to grow alfalfa.

Coming back to the Tri-County Project. We do not grow alfalfa there because the subsoil is dry. It has never rained enough to wet it. It will hold 2 to 2½ inches more water per foot; 6.5 inches per foot, about 3 feet of subsoil, will produce one ton of alfalfa hay. We have in that sub-

soil a reservoir for water in wet year or dry year. We can irrigate that soil whenever we have water to put on it. We can soak it 35 feet deep and pump it all out again with alfalfa in five years; then soak it up again and pump it out.

We can raise alfalfa there for the balance of our state where the alfalfa acreage is gradually decreasing. If we can achieve the modest but perfectly possible increase of two tons per acre per year from supplemental water, in addition to the ton or so that rainfall will produce, a tonnage that is possible on 13 inches of stored water, hire it cut for half, and sell it for \$10.00 per ton, our water will gross us practically \$10 per acre-foot.

In addition we can plow up alfalfa sod in the spring, irrigate in the spring, and plant to corn and with some July water, produce a quantity of corn which with alfalfa will make cattle feeding a dominant industry. We will have achieved in the heart of supplemental irrigation territory, in an area already colonized by substantial, intelligent, education-loving people, a sound reclamation.

In my opinion irrigation, in regions where precipitation alone is occasionally fully adequate for general farming, can be made a success, if the soil is fit, if the water can be had, and if construction is not too costly, providing farming systems can be devised which will utilize water every year whether drought comes or not.

Drouth and Its Relation to Supplemental Irrigation¹

By J. C. Russel²

ONE of the peculiarities of the climate of the Great Plains is the frequent occurrence of more or less prolonged dry periods during which little or no rain falls. These periods, commonly called drouths, are a serious handicap to successful crop production.

An illustration that might be cited is the drouth that affected twenty southern Nebraska counties in 1926. From September 1, 1925 to July 1, 1926, an average of only 4.10 inches of rain fell in rains of consequence, that is, in daily rains of over 0.5 inch each. July and August 1926 were drier than normal. As a result the average yield of corn for these counties in 1926 was 4.7 bushels per acre. The average for the preceding 22 years is 22.8 bushels. The yield of wheat was reduced to 6.6 bushels, the average for the preceding 21 years is 14.8 bushels. The yield of oats was reduced to 8.8 bushels as compared with 26.0 bushels, the average of the preceding 22 years. The yield of alfalfa was reduced from 2.70 tons per acre, the 21-year average, to 1.78 tons.

At 1926 cash sale prices this drouth meant, to the 24,000 farmers who reside in those counties, a loss in expected gross income from farm crops of \$43,850,000 or \$1830 apiece, or 66 per cent of their expected gross income from crops.

This drouth was not only a loss to the farmers but it was a loss to people in towns, to bankers, and to merchants through whose hands the 44 millions of dollars would have passed, and to railroads which would have hauled out of these counties many more carloads of produce, and in again the carloads of goods which would have been purchased.

It was also a sizable loss to the state of Nebraska for these twenty counties contain one-fourth of the total cultivated acreage of the state and one-fifth of its farm population, and it produces normally one-fifth of its corn and alfalfa, and one-half of its wheat.

It is the realization of the enormity of loss from drouth that has focused attention in the last few years on the possibilities of supplemental irrigation. Supplemental irrigation is the practice of artificially supplying to the soil sufficient water to carry crops through periods of drouth, and to make up the difference between the crop requirements and rainfall in seasons when rainfall alone is inadequate.

The purpose of this paper is to discuss the frequency and nature of drouth periods, their effects on yields, and the possibility of minimizing their effects by supplemental irrigation. The season and character of drouths varies with latitude and locality. This paper will deal with the central Great Plains, particularly a portion of it in central Nebraska, a potential 450,000-acre supplemental irrigation project.

There is no regularity in the occurrence of drouth in the Great Plains. In Nebraska serious, prolonged, comparatively rainless periods may occur any time between April 1 and October 31. Just what constitutes a serious dry period is debatable. Some prefer to consider any period of over 30 days within which the total rainfall is less than 1.00 inch as a period of drouth, when it comes during the growing season. Others would take into consideration the character of the rains. In Nebraska we consider that any isolated rain of less than 0.50 inch coming during the open season is comparatively ineffective, particularly from the standpoint of its penetrating a silt loam soil deeply enough to be absorbed by crop plants. Consequently we are inclined to disregard all rainfall coming in rains of under 0.50 inch, and generally consider the rains of over 0.50 inch in depth as the effective rainfall. In some studies which we have had occasion to make on the frequency of drouth in central Nebraska, we have considered a drouth as a period of 30 days or longer within which less than 1.00 inch of effective rain falls, an effective rain being defined as a daily rainfall of over 0.50 inch, or two consecutive daily rainfalls of over 0.25 inch each.

¹Paper presented at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers at Kansas City, Mo., December, 1929. A contribution from the department of agronomy, Nebraska Agricultural Experiment Station and published with the approval of the Director as Paper No. 92 Journal Series.

²Professor of soils, University of Nebraska.

³Burr, W. W., and Russel, J. C. Report of certain investigations on the central Nebraska Supplemental Irrigation Project. In 15th Annual Report Nebraska State Department Public Works, 1923-1924, p. 199-239.

Fig. 1 shows the frequency and extensity of dry periods at Holdrege, Nebraska. During the 26 years shown in the figure, 65 dry periods averaging 48 days in length have occurred, the average effective rainfall during these periods being 0.44 inches.

In selected instances the effect of conspicuous drouths have been notable. In 1913 the two drouth periods together reduced the yield of corn to 0.5 bushel per acre, and the dry fall of 1912 and spring drouth of 1913 reduced the wheat yield to 8.0 bushels. In 1918, the wheat yield was 10 bushels, and the corn yield 16.0 bushels. In 1920, a year of unusual dryness (58 days with only 0.50 inch of effective rain) corn yielded 25.0 bushels, and wheat 13.0 bushels. In 1923 wheat yielded 5.0 bushels and corn 31.0 bushels, the former being due to the unusual fall of 1922, a drouth of 109 days with only 0.68 inches of effective rain. The higher corn yield was due to 14.79 inches of effective rain before the summer drouth of 1923 began. In 1926 wheat yielded but 5.0 bushels and corn 6.0 bushels, due to the prolonged drouth beginning in August 1925.

A very detailed study of yields in relation to drouth periods shows very clearly that an abundance of moisture preceding a prolonged dry period can very largely mitigate its seriousness.

Consider first the case of corn, a crop that is supposed to be very seriously affected by drouth in July and August. The moisture which corn requires begins

to accumulate along in September of the preceding fall, and should continue to accumulate until along in June. From then on it is withdrawn by the rapidly growing crop faster than it is ordinarily replenished by the July and August rains, and if the latter should be deficient, the crop may suffer, particularly if the accumulated total is deficient. If the soil is well supplied the crop may withstand a considerable deficiency of July and August rainfall.

Fig. 2 shows a dot correlation of corn yield with rainfall based on crop and weather data for Adams, Kearney, and Phelps Counties in the proposed Tri-County Supplemental Irrigation Project in central Nebraska. The period covered is from 1905 to 1929. The coordinates of each dot is a county yield in bushels per acre and the corresponding effective rainfall for the crop season. The rainfall considered is the total of rains in excess of 0.50 inch each, from September 1 to July 1, excluding the winter months January, February and March. The large dots indicate cases in which the July and August rainfall (over 6 inches) was high, and the circles cases in which July and August rainfall was low (under 2 inches).

Table I to be considered in the same connection shows the average yield and effective rainfall by groups. Definite correlation of yield with effective rainfall up to July 1 is indicated. The correlation with July-August rainfall is very indefinite, or lacking: In only one year (1913) is it unquestionably true that corn was ruined by July or August drouth in spite of a fairly adequate water supply previous to July 1.

The relation of wheat to moisture supply is considerably more complex than in the case of corn. Wheat is critically affected by moisture at two seasons, and extreme shortage in either has no

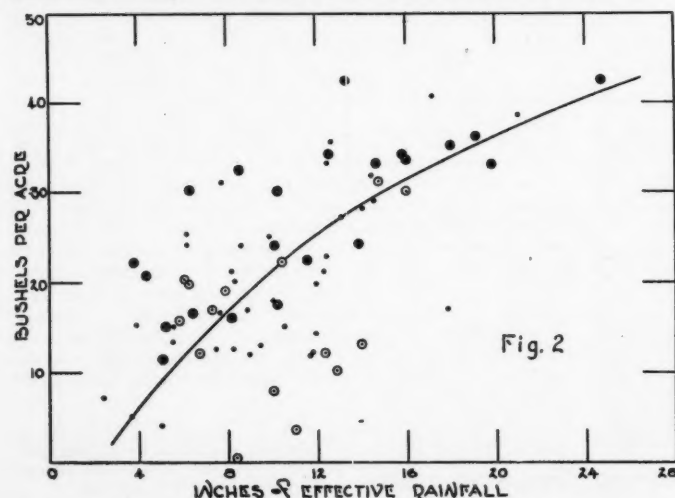
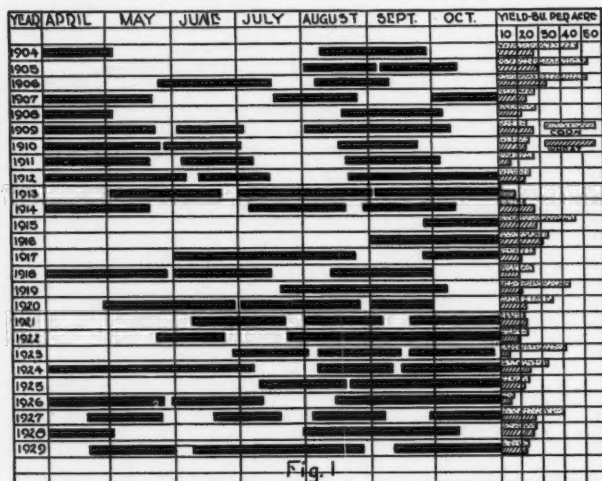


Fig. 1. (Left) The frequency of dry periods at Holdrege, Nebraska. Each period is over 30 days in length and received less than 1.00 inch of effective rain

Fig. 2. (Lower left) The correlation of corn yields with effective rainfall in Adams, Kearney, and Phelps Counties, Nebraska, during the period, 1905 to 1929. The effective rainfall includes daily rains of over 0.50 inch each coming during the period, September 1 to June 30, excluding precipitation in January, February and March. The large dots indicate cases where the effective July and August rainfall exceeded 6.00 inches. The circles indicate cases where the July and August rainfall was less than 2.00 inches

Fig. 3. (lower right) The significance of the combination of fall and spring rain for wheat production in Adams, Kearney and Phelps Counties, Nebraska. The large dots indicate yields of wheat in excess of 17.4 bushels, and the circles indicate yields of wheat less than 12.0 bushels per acre

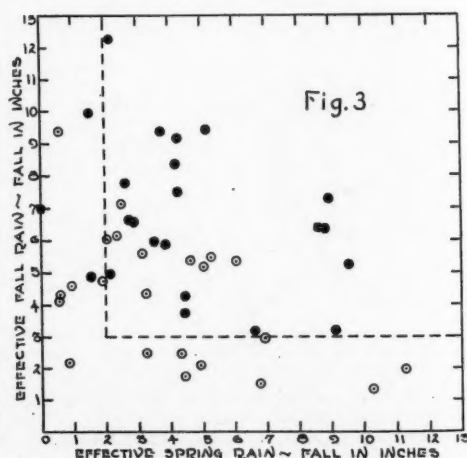


TABLE I

Relation of Corn Yield in Three Nebraska Counties to Effective Rainfall
(Rains coming in showers of over 0.50 inch each during September to December, April to June, and July and August)

Group (bushels per acre)	Number aver- aged	Average yield per acre, bushels	Effective rainfall up to July, inches	July rainfall, inches	August rainfall, inches	July and August rainfall, inches
35.1 to 42.3	7	36.5	17.61	4.13	3.93	7.06
32.0 to 34.0	8	33.1	13.54	3.59	3.66	7.25
27.0 to 31.7	9	29.7	12.18	2.05	1.71	3.76
22.4 to 25.0	8	23.9	9.82	1.77	3.45	5.22
19.0 to 22.0	9	20.6	8.11	2.58	1.48	4.06
15.2 to 18.0	8	16.7	7.51	2.55	1.63	3.98
12.3 to 15.0	8	13.6	7.59	1.82	1.41	3.23
4.0 to 12.0	8	9.1	7.41	1.26	2.23	3.49

winter is very dry so that wheat winter kills or is badly damaged, or blows out, no amount of rain in the spring can make a good crop. On the other hand, if April and May are very dry, which permits blowing, no amount of fall storage can make a good crop. June rainfall is not very important if the previous moisture supply is even fairly adequate.

Fig. 3 is a graph of high and low wheat yields during the 1905 to 1929 period in Adams, Kearney and Phelps Counties, Nebraska, arranged to show the importance of both fall and spring rainfall. In the fall rainfall is included all rains of over 0.50 inch from August 1 to January 1. In the spring rainfall is included the 0.50 inch rains in April and May.

It is obvious in the figure that high yields are obtained by high fall rainfall coupled with spring rains in excess of some small value, or by high spring rainfall coupled with fall rains in excess of some small value. Relatively the fall rains are the more important. No high yield is obtained unless fall rain is in excess of 3 inches, but there are three cases in twenty-three where high yields have been obtained on a spring rainfall of less than 2 inches.

A considerable number of low yields occur in some years, even on what appears to be adequate rainfall for high yields in others. This is precisely what one would expect. High yields cannot be obtained on low rainfall, for moisture sets a limit to production, but low yields can be obtained on high rainfall in the case of a crop like wheat, where temperature and soil fertility sets a limit to production.

Table II shows more completely the frequency of various yields in relation to quantity of effective precipitation. In 71 cases divided into three groups of high, medium, and low yields, there have been 47 cases of fall rains in excess of 3 inches, and spring rains in excess of 2 inches. In 20 cases the yields have been high; in 17 cases, medium; and in 10 cases, low. In 9 cases where fall rain has been less than 3 inches, all yields have been low. In 16 cases, where spring rains have been less than 2 inches, yields have been high 3 times, and medium and low 7 times and 6 inches, respectively. In 24 cases where fall rain was more than 6 inches, and spring rain more than 2 inches, yields have been high to medium 22 times.

The three Nebraska counties for which the data in previous figures and tables apply include within their borders probably one of the largest prospective supplemental irrigation projects, and from the standpoint of soil quality and irrigability probably one of the best projects that can be found anywhere in supplemental irrigation territory. An interpretation of drought periods and yield to rainfall correlations in the light of utilization of supplemental water is therefore highly pertinent.

Three questions arise. First, what conclusions can be drawn relative to the frequency of the inadequacy of rainfall alone, and how frequently should rainfall be supplemented? Second, when should supplemental water be applied? Third, what increase can be expected from its use?

In the case of corn the highest county yield has been 42.3 bushels which is not a notably high yield for good quality soil. In only 3 years out of twenty-five have coun-

TABLE II

Relation of Wheat Yield in Three Nebraska Counties to Effective Fall (August to December) and Spring (April and May) Rainfall

Class	Fre- quency	Yield per acre, bushels	Fall rains, inches	Spring rains, inches	Fall and spring rains, inches
Total - 71 cases - 3 counties - 24 years					
High	23	20.5	6.74	4.57	11.31
Medium	24	14.3	6.78	3.31	10.09
Low	24	8.5	4.26	3.99	8.25
47 cases - more than 3 inches rain in fall and more than 2 inches rain in spring					
High	20	20.9	6.66	5.11	11.77
Medium	17	14.2	6.92	4.17	11.09
Low	10	9.2	5.64	3.61	9.45
9 cases - less than 3 inches rain in fall					
High	0	-	-	-	-
Medium	0	-	-	-	-
Low	9	7.5	2.07	5.90	7.97
16 cases - less than 3 inches rain in spring					
High	3	19.9	7.28	1.03	8.31
Medium	7	14.6	6.42	1.21	7.63
Low	6	8.0	4.90	0.91	5.81
24 cases - more than 6 inches rain in fall and more than 2 inches rain in spring					
High	12	23.0	8.05	4.88	12.96
Medium	10	13.9	8.63	4.21	12.84
Low	2	5.7	6.58	2.27	8.65

ty yields been limited by too much water at the wrong time. These were in 1905, 1906 and 1915. Yields have exceeded 32 bushels as a county average only about one year in five. In four years out of five yields are low primarily on account of too little water. About half the time yields are less than 24 bushels per acre.

To convert yields which average 13.6 bushels into yields which average 33.1 bushels (Table I) require 5.95 inches of water for each 19.5 bushels of corn or about one inch for each 3 bushels. On the basis of the performance of corn on natural precipitation, when it comes in fall or spring in adequate quantity, it seems reasonable to expect that supplemental water applied in the fall or early spring in quantities from one-half to one acre-foot will increase yields on the average fully 20 bushels per acre. Additional water to apply in July in periods of extreme summer dryness should make possible large enough yields in dry years to offset any detriment of excessive fall or spring irrigation in case the season later turns out wet.

Wheat yields have been satisfactorily high (over 20 bushels) only about one year in six, and unsatisfactorily low (less than 12 bushels) one year in three. The quantity of water required to convert low yields into high is not as definitely recognizable as in the case of corn. In practice supplemental irrigation for wheat will need to be employed in the fall before wheat is seeded. The August or September rainfall is rarely high enough that it would be safe not to irrigate; in only one year in three does the total fall rainfall exceed six inches, so that supplemental irrigation seems fully justified two years out of three. In only one year in twelve is spring rainfall so low as to seriously limit production when fall moisture is adequately large. Only in rare cases, if at all, is spring moisture excessive, so that fall irrigation would not be detrimental.

All too frequently in years of favorable wetness is wheat yield reduced by lack of fertility which cannot be safely maintained at a high level in drouthy regions. If supplemental water were available so that fertility could be maintained, it seems very probable that consistent irrigation would increase the average wheat yield to over 20 bushels per acre. The present average is 14.2 bushels. In practice from 3 to 6 inches of water would need to be applied each fall to insure adequate total supply. An average increase of only six bushels in yield from this quantity of water would be worth while. According to water requirement ratios of Briggs and Shantz, and others, it theoretically takes about twice as much water for a bushel of wheat as for a bushel of corn. If this be the case in practice, and 6 to 12 inches of supplemental water will produce 20 bushels increase in corn, 6 bushels increase in wheat from 3 to 6 inches of water is not improbable.

Land Reclamation for Efficiency¹

By E. R. Jones²

SUFFICIENT land reclamation on every farm to make it a well-balanced production unit is the job of the moment for the land reclamation engineer. That means draining the wet spots in the cultivated fields; laying out fields rectangular in outline so that fewer turns and less labor are necessary; keeping hillsides from washing and gullies from ruining the farm; removing the tramp stump or rock that now interferes with plowing; and clearing enough more acres to make the grub-stake settler's farm self-supporting. The latter should either quit trying to farm, or else get more clear land on which to operate. If he is the only settler on a three-mile road through the brush, swamp and forest, he had better get out. If he is one of the three settlers on a mile of road, he has a chance to succeed, but only by reclaiming enough of the land to make it a farm.

High Rent Justifies Expansion. When a farmer is considering the addition of 20 acres of tillable land to his farm, let him ask himself this question: Will 6 per cent interest on the cost of improvement be less than the rent I would have to pay for a similar 20-acre field of land adjacent to my farm? "Yes" means land reclamation. "No" means renting.

Likewise, in the creation of new farms, let no new extensive reclamation project be undertaken except where the finished farms carved therefrom, including the cost of buildings, reclamation works, roads, schools, town halls and churches, is less than what similar improved farms can be bought for today. So long as banks and insurance companies have long lists of such farms among their holdings for sale, the day of land reclamation projects to create new farms must be held in abeyance. The salvation of agriculture depends upon the complete reclamation of the farms now existing.

The American Farm Irresistible. The corporation farm, the supervised chain of farms, and the small one-family farm—all three have permanent places in American agriculture. Each type of farming satisfies a particular demand. Each can prosper without stepping on the other's toes. Each can be developed in such a way that each unit of each type will contribute to the wealth of the nation and the prosperity and contentment of the operator. Then will we hear the cry "The more good farms, the better" instead of the popular slogan of today, "Too many farmers."

After Farming, What? I do not look for the rural population of America to become any less than it is now, either numerically or proportionately. It has reached the rock bottom figure of 25 per cent, and is about at a standstill. It is more apt to increase than to diminish.

Granted that only 10 per cent of the American people with improved land and modern machinery could produce enough to feed themselves together with the other 90 per cent of the population, are we ready to reduce our rural population to that low figure?

Where would the 15,000,000 people go, that some economists are asking to leave the farms? No apprenticeships are open in the city barber shops, because they say that profession is also crowded. The same is true in the case of the plumber, the carpenter and the electrician, if we are to judge by the zeal of the labor unions in guarding their jobs.

Is America Too Large? America has promised every one of its 120,000,000 people an opportunity for life, liberty and the pursuit of happiness. Are we ready to admit that

both city and country are too crowded? That America would be better off with less territory and fewer people? That Thomas Jefferson brought a curse on this country when he purchased the Louisiana Territory, or that Lewis and Clark clinched it by blazing a trail to Oregon? Would we be better off if Florida were still Spanish, or the Ohio Territory still British? Shall we give California back to Mexico, or Maine back to Canada? What a blessing we didn't win with "fifty-four forty or fight." Whom do we mean by "we"? Is it the part to be cut out or is it that which would be left? Which is the tail, and which is the dog? Who would decide?

Thank God that decision was made at Plymouth Rock. There is a way of making every square mile of our land a national asset, and every home a unit of national wealth. All this without reducing the number of farm homes. We can justify an increase in the number of farms, and exodus of some of the country-minded men from the city back to the small farm where they could live well, educate their children, and die happy, whether rich or not.

I have in mind a modest farm home, home enough for a family of five or six persons to live with modern conveniences, buildings and machinery enough for 80 acres of land, three-quarters of the larder filled with the products of the farm, selling \$1000 worth of red raspberries each year from a small patch, and selling another \$1000 worth of beef cattle, wool, turkeys, or any other commodity of which there has been an actual scarcity for the last 10 years or more. Perhaps eggs at 60 cents a dozen. Such a farm makes a good home for a family which is an asset to the nation, yet does not hurt anybody by contributing to the so-called surplus. Would not such a farm enrich any countryside? Can there be too many of them?

Let large blocks of our undeveloped land be reacquired by the federal government and held as forest and wild life preserves for the present, perhaps for 100 years. But let always the door be kept open for the reclamation of the better of those areas to make homes for more contented families whenever and wherever economic conditions warrant such expansion.

Extending our Markets. I look for the Federal Farm Board to reduce the so-called surplus by getting our farmers to raise crops that will take the place of commodities that are now imported. Why should 60,000,000 pounds of peanuts be imported to the United States each year? Likewise 15,000,000 pounds of soybean oil from Japan for 12 cents a pound? We can produce those crops here, and would if attention were properly directed thereto. We can't raise bananas, but we can raise the apples to take their place, and meet banana propaganda with good salesmanship of apples.

We know that China can not afford to buy our 200,000,000-bushel surplus of American wheat. If they could, there would not be any surplus, because surplus is determined largely by the buyer's inability to pay. However, would it not help the situation if some statesman could work out a way by which a preferential tariff on Chinese goods would operate, dependent upon their purchasing certain American farm products?

Corporation farming and supervised farming, where from 10,000 to 100,000 acres are under one management, have earned a lasting foothold in American agriculture by introducing greater efficiency into production. Their profits depend upon big quantities and low cost of production. They cannot, however, put the small farmer out of business, because he can always turn his attention to those commodities that do not lend themselves to mass production. If the big fellow raises wheat, the little fellow will raise strawberries, and both will prosper.

¹Paper presented at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers, at Kansas City, Mo., December, 1929.

²Professor of agricultural engineering, University of Wisconsin. Mem. A.S.A.E.

Supplemental Irrigation on the Atlantic Coast¹

By F. E. Staebner² and G. A. Mitchell³

FOR the last year or two the development of supplemental irrigation along the Atlantic Coast has been chiefly in the states of Florida, Virginia and New Jersey. In Florida the continued expansion of the sub-irrigated truck acreage and the surface irrigated citrus orchards has been added to by the installation of a number of spray irrigation outfits intended primarily for frost protection. These latter are for the protection of winter-grown vegetables and are all located on the reclaimed peat soils of the Everglades. In Virginia a wide and growing interest is found in the irrigation of potatoes and apples. The installations so far made in commercial potato fields have been largely experimental but at least one permanent installation has been made in the apple belt. In both fields the excellent results recently obtained have had the effect of increasing interest in the subject. In New Jersey the number of acres under spray irrigation is continuing to increase steadily; it is, of course, all for truck crops. Irrigation with sewage is practiced by certain state institutions.

Surface Irrigation in Florida. The surface irrigation plants in Florida are used mainly for the irrigation of citrus fruits. Florida is well supplied with flowing artesian water; it is probable that substantially half the acreage watered is supplied from flowing wells. Present practice indicates that a 4-inch flowing well will irrigate about 10 acres and a 6-inch well about 20 acres. This would indicate, very roughly, an average irrigation capacity of nearly $3\frac{1}{2}$ inches per ten days. For the remainder of the acreage the water is pumped, partly from wells and partly from lakes or other surface sources. The water in the wells is generally raised from a depth of from 10 to 40 feet. From the open bodies of water the lifts are in most cases somewhat less, and a considerable acreage is irrigated with a total lift (suction and discharge combined) of not over 15 or 20 feet. The power generally is furnished by internal-combustion engines, although the use of electricity is increasing. Kerosene is probably

the most widely used fuel. Horizontal centrifugal pumps are the most common, but a few of the vertical type, set in pits, are in use. An occasional air lift is found.

Where there are so many flowing wells, it is not surprising that open-ditch systems are found. It is perhaps more unexpected to learn that on most of the surface irrigation systems pipe is used to convey water to the final distributing point. This is done in both iron pipe systems and in terra cotta pipe systems—probably about half and half—the latter, of course, operating under a low head.

A number of failures have occurred where terra cotta pipe has been used. Many engineers feel that such failures are due to the fact that terra cotta pipe can stand no internal pressure. The authors believe this is a mistake, and that a maximum pressure head of 10 or 15 feet may be put on such pipe if properly installed. A sufficient number of systems giving satisfaction are in operation to indicate that the difficulty in such cases lies elsewhere than in the hydraulic pressure. One common cause of failure has been insufficient coverage of earth over the pipe, so that breaks were caused by the passage of a heavily-loaded wagon or a tractor. It is felt that a minimum coverage of 14 inches should take care of this, although more may be desirable. A shallow coverage might permit sufficient temperature change as between summer and winter to cause breakage. In fact, the present tendency to use bituminous sewer-pipe joint compounds may be an acknowledgment of temperature changes as a cause of trouble. It would seem that pipe lines put together with such material would permit sufficient expansion and contraction to prevent any breakage from that cause. Another proposal, offered by men using terra cotta pipe lines put together with unyielding joints, is that wherever possible the pipes be laid above the ground surface. So located, breaks may be seen and the repairs more easily effected. In few cases, however, could such a pipe line be laid on the ground surface without interfering with farming operations.

Iron pipe systems get away from this difficulty of breakage but the common screwed-joint pipe of commerce is expensive. Moreover, it rusts and pits badly under Florida conditions, making its installation of doubtful advisability. The lighter weights of riveted steel pipe have disappeared from use owing to their short life.

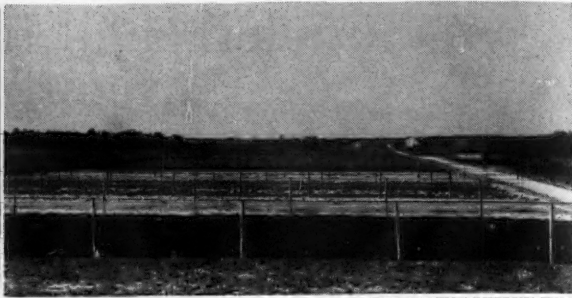
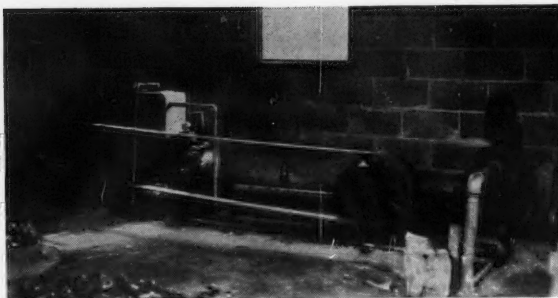
¹Paper presented at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers, at Kansas City, Mo., December, 1929.

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(Left) A low-pressure terra cotta pipe irrigation distribution system under construction. (Middle) Removable plug with pipe and valve used for admitting water to stop-pocket and tile lateral at the time of irrigating. (Right) A patented quick-acting irrigation valve or outlet that is widely used



(Left) Typical pumping plant for a spray irrigation outfit. (Right) A typical installation of an overhead spray irrigation system

Cast-iron pipe may be the solution of the piping problem. It is expensive, but it is durable and will withstand considerable pressure. For most irrigation purposes the lighter weights of this pipe serve admirably. For low pressures the extra-heavy cast iron soil pipe may well be used, and for somewhat higher pressures the Class A water pipe or the standard gas pipe. Such pipe must be protected from direct impact but this is generally not difficult in irrigation service. Well-made concrete pipe should be satisfactory in this service but no installations using it have come to the authors' attention.

Six-inch and 8-inch main pipe are the sizes in most common use and these irrigate orchards varying from 20 to 60 acres in size. Large pipes are particularly important when irrigating from a flowing well. In fact, it is excellent practice to connect the flowing well to the main below ground, instead of above ground. Even the 3 or 4 feet of difference in the elevation over which the water must be forced by natural pressure may markedly increase the flow and so speed up the irrigation when delivering water from the outlets at the lower elevations.

The outlets are located at varying distances from about 30 to about 200 feet, but recent practice favors an outlet in every third middle. From the outlets the water is conducted the necessary distance to reach the intermediate middles, either by a semi-permanent ditch constructed for the purpose or by slip-joint pipe. The latter is the more common method.

The outlets recently installed have been mostly of 3 or 4-inch size, although 6-inch is used. For iron pipe systems standard 3-inch valves are employed. For terra cotta systems a 4-inch iron pipe nipple cemented into the end of the riser pipe that comes from the underground main is common. Such outlets are closed by a standard 4-inch iron-pipe cap. They are cheap but cause much difficulty due to the rusting of the caps in place during the long season when not in use. Coating the threads with graphite grease reduces this trouble. Also many western-type alfalfa valves and specially designed quick-acting valves are used. The latter give excellent service but are expensive. There seems to be a definite need for a simple, cheap, but effective means of controlling the issuance of water from the openings of low-pressure systems.

Final distribution is down the middles between the trees. It is, of course, important that the main pipe or laterals be located along high land so that the water when released can flow away over the ground on one or both sides of the outlet valves. Very often the water is merely turned loose in the middle upon leaving the valves, although many make a group of furrows to guide the water, and a few further support this with a substantial amount of hoe or shovel work. In spite of the generally sandy character of the soil the water runs from 300 to 500 feet down the middles; however, better irrigation is possible when the runs are shorter.

A surprising amount of final distribution is done with slip-joint pipe, although this is confined largely to sys-

tems using pumped water. Many use this method who have suitable topography for furrow methods, in spite of the increased labor involved, because of the saving of water and the better distribution obtained. The individual pipe sections are uniformly 10 feet long. Four and 6-inch pipes are used. A total length of 350 feet in one direction from one outlet seems to be satisfactory.

Subirrigation in Florida. Although some subirrigation of citrus is practiced in Florida, most of such acreage is for winter vegetables, especially celery and potatoes. Practically all of the water is supplied by flowing wells. The nearly-level, pervious top soil underlain by hardpan or clay at a depth of from 18 inches to 3 feet, as is found in many parts of Florida, gives favorable conditions for subirrigation of vegetables; and where the subsoil is 4 to 6 feet deep it may be used for citrus. The largest part of the acreage is subirrigated by the open-ditch system, the combined system of supply and drainage ditches sometimes enclosing blocks up to 10 and 20 acres in size. In general the block is crossed by laterals spaced 300 to 400 feet apart. These mains and laterals are perhaps 1½ feet wide on the bottom and 2 feet deep. Occasionally a tract is found where the blocks of land thus set off are irrigated successfully from these ditches alone. At suitably chosen points stop or check gates are placed in the ditches to hold the water at the desired level. These gates are generally of wood.

In most cases, however, the mains and laterals alone are not depended on to irrigate the tract, but the whole is divided into beds 8 to 40 feet wide and the water level in the ditches raised to such a point that the dead furrows between the beds will be constantly wetted with surface water. This bedding of the surface help markedly in securing uniformity of irrigation. Where the beds are narrow (8 to 12 feet) excellent irrigation is accomplished in almost any section where the system is used.

A very large acreage is subirrigated through underground tile systems. This method also requires that the top soil be pervious and underlain at a suitable depth by an impervious subsoil. For this system there is generally provided a main supply line along the high part of the tract and if necessary branches along the ridges. These are commonly of vitrified clay sewer pipe with tight joints. At suitable locations along this supply line, so-called "stop-pockets" are placed. These are used as connections between the supply mains and the 3-inch tile laterals which accomplish the underground distribution of the water. By means of wooden plugs, the entrance of water from the main into the stop-pockets, and so into the laterals, is controlled. Some evidence that the wooden-plug control is not fully satisfactory was found in a number of recently installed systems, in which a 1-inch iron pipe of suitable length was tightly fitted into the wooden plug, and a valve attached to the opposite end of this short pipe. By means of this valve the flow of water into the stop-pocket, and so into the tile distribution lateral, may be adjusted to suit. These lateral lines which run down the slight slope are composed of one-foot lengths

of 3-inch tile just touching one another and with the joints unsealed, as in drainage practice. They are commonly laid from 16 to 18 inches below the ground surface and from 18 to 24 feet apart. The grade on these lines generally ranges from 1 to 3 inches per 100 feet. From the open joints the water seeps into the surrounding soil. At suitable intervals along these tile lines (generally 100 to 400 feet) stop-pockets are placed. These are variously arranged, their object being to hold the water in the upstream side of the lateral at a somewhat higher elevation than would otherwise be the case, and thereby force it a little more rapidly into the subsoil. At the far end each of these laterals is connected, through a stop-pocket, with a main-drain pipe line which is also of terra cotta.

Subirrigation systems have never been fully standardized and many other arrangements and methods will be found. Iron-pipe supply mains (2½-inch) are sometimes used. In such a case they often discharge through 1-inch valves into closed-bottom stop-pockets from which the lateral distribution tiles lead off at the side. Where the steeper slopes are encountered (although yet quite flat when compared to some regions), the supply mains are run down the grade and the laterals substantially on the contours.

The one notable tendency at present in subirrigation through tile, is the effort at better control of the water through valves with adjustable openings.

Spray Irrigation for Frost Protection in Florida. Spray irrigation for frost protection, as at present practiced on the peat lands of Florida is serving a real need. The development at present is of the whirling-spray type of nozzle of large capacity. Each nozzle, operating under a pressure of not less than 30 pounds per square inch, sprays water over a circular area somewhat more than 50 feet in diameter. These nozzles discharge from 40 to 45 gallons per minute each, putting a requirement of 700 to 800 gallons per minute per acre on the pumps. This represents 70 to 100 times the pumping capacity ordinarily required for spray irrigation and indicates the necessity for an abundant water supply and a large capital investment in pumping plant. Viewed from another standpoint it means applying water to the land at a rate 10 to 18 times as great as that at which it is usually applied to an area at any one time being wetted under usual spray irrigation conditions. This indicates a need for excellent drainage facilities.

Surface Irrigation in Virginia. Leaving Florida and going northward into Virginia, we find irrigation of potatoes is being done there under favorable low-lift pumping conditions, and with simple equipment. The outfits at present are not intended as permanent construction but a number of systems are in operation and impressive increases in yield and quality of potatoes are being obtained.

As mentioned earlier, one permanent installation for

the irrigation of apples has been made in the orchard section of Virginia. This plant covers nearly 60 acres. It has an electrically driven, direct-connected, single-stage centrifugal pump with a capacity of 900 gallons per minute or substantially 2 inches in depth over the entire tract in 6 ten-hour days. The suction pipe of this pump takes its water from a river through a 12-inch terra cotta supply pipe about 130 feet long, 110 feet of which next to the river operates by gravity and the remainder by suction. The discharge line is 8-inch cast-iron pipe and the outlets are specially cast tee riser fittings equipped in the main with standard 3-inch valves. Two or three 4-inch valves are installed where the topography is such that a relatively large area may be reached from one outlet. A large quantity of high-quality fruit was obtained in last summer's unusually dry season.

Spray Irrigation in New Jersey. Overhead irrigation has had a rapid and steady development in New Jersey during the last twenty years. It is now unusual in Cumberland County, for instance, to attempt to produce without irrigation the more profitable vegetables for the city markets.

The growth of this method of market gardening has been particularly rapid on the small truck farms around Vineland, while perhaps the largest area under overhead irrigation which is under one management is the Del-Bay Farms, formerly known as the Seabrook Farms. Both Vineland and the Del-Bay Farms are in Cumberland County in southern New Jersey and depend quite largely on the New York market although much produce is shipped to Philadelphia and sold at the shore resorts and in local markets.

Overhead irrigation is an important factor also on farms in northern New Jersey and on Long Island that are located near New York City. Development near New York City, however, has been hindered by the rapid growth of the population of its suburbs.

The soil of southern New Jersey is sandy. Rocky subsoil does not occur. For this reason wells are driven easily and these wells are the source of most of the irrigation water in this part of the state. In driving a well, 1¼, 1½ or 2-inch iron pipe fitted with a fine-mesh point, is driven into the ground by an iron weight to which is fastened a guide rod sliding up and down in the pipe, this being held in place by a special cap with a hole for the guide rod. This cap also serves to protect the end of the driven pipe. The weight is sometimes raised by two men grasping handles extending from its two sides. More often it is raised by a rope over a pulley which is suspended from a tripod. Two-inch pipe is the largest that can be driven in this way. If a larger well is desired, pipe 4 inches and upward in diameter is used. These larger wells are put down with sand buckets and a fine mesh point, or a Cook strainer is used.



(Left) Irrigating a corn field with sewage after crop was harvested. The field has been in corn many years and irrigation practiced the year round. (Right) This is a subirrigated vegetable field. The stop-pockets along the main supply line are shown at the ends of the rows. From these stop-pockets the tile laterals take off

The advantage of the larger wells is that it is possible to determine the nature of the water-bearing sand and thus to avoid one of the pitfalls of the driven well, namely, that of its soon ceasing to give a good flow because of the fineness of the sand about the point.

The source of water, whether it be city main connection, well, or open body must yield not less than $7\frac{1}{2}$ gallons per minute per acre over the entire area irrigated. This quantity will permit the application of one acre-inch of water per acre in six 10-hour days. It must be available in the driest time. As the entire acreage is not usually watered at any one time, the theoretical installed-nozzle capacity of these outfits varies from 45 to 70 gallons per acre per minute at an assumed operating pressure of 40 pounds per square inch. A number of measurements of pressures in operating systems have been made by means of a pressure gage and no pressures approaching 40 pounds were found. This of course indicates that many systems have an actual nozzle capacity well below that given above. Some established commercial systems were found with nozzle pressures below 15 pounds to the square inch. This low operating pressure brings the nozzle capacity down to less than 30 gallons per acre per minute, and thus well below the one inch in six 10-hour days, as previously mentioned. When it is realized that these systems are operated less than 200 hours per year, on the average, it is surprising that these expensive irrigation plants should be so necessary in the farm economy of a humid section.

Gasoline engines are the usual source of power for the pumping plants, although with the extension of power lines the use of electricity is likely to increase.

Where the water supply is a lake or stream, as is likely to be the case with the larger outfits, centrifugal pumps are found but double-acting, horizontal-cylinder displacement pumps are by far the most common. Among equipment for spraying 4 acres, a 5-horsepower gasoline engine and a 6-inch plunger pump is commonly seen.

It seems to be the custom at the present time for a farmer, in starting his irrigation enterprise, to buy an engine and pump large enough to enable him later to increase his irrigated area. Most of these areas in Cumberland Company have been so increased during the past twenty years. Many of these farms started with from one to three acres. Their growth has extended from this upward to ten acres. A few are larger than this, one containing some 300 acres. However, the small irrigation farm seems to pay best and more than half of the irrigated areas are less than 5 acres in size.

Twenty years ago the strawberry crop was considered one of the best for overhead irrigation. Now strawberries are rarely grown under pipes. This may be due to the fact that one year of plant growth is required before a crop can be secured, and that only one crop a year can be grown with most varieties, while if vegetables are grown two and three crops can be taken off irrigated land in one season.

The crops commonly grown under overhead irrigation in New Jersey and in neighboring states, in the order of the acreage grown in New Jersey, are lettuce, spinach, celery, beets, carrots, string beans, cabbage, onions, flowers, radishes and cauliflower. One hundred acres or more of each of these crops are grown under spray irrigation in New Jersey. Smaller areas of many other crops are raised.

Five acres of land under irrigation, farmed as in Cumberland County, New Jersey, will support an average family. In this case most of the work of the year is done between March 1 and November 1. A recent survey of irrigation in New Jersey by the state agricultural experiment station showed that five acres irrigated usually proved a more satisfactory business enterprise than a fifty-acre truck farm devoted to less intensive vegetable production.

Sewage Irrigation in New Jersey. Sewage irrigation has been practiced at public institutions in New Jersey

for more than ten years. During this time it has been demonstrated that sanitary disposal of the sewage can be effected by proper operation of a suitable system and that it is possible to grow at a profit crops against which no valid objection can be raised from the standpoint of health due to the fact that sewage is the irrigating medium. It has also been established that it is essential that a type of equipment be installed that will permit the ready distribution of the sewage. To do this it has been found desirable to transport the water in underground pipes direct to the points in the field where the distribution begins. At those points riser branches are brought up from the underground pipes and so arranged as to discharge the irrigation water through suitable openings at ground level. These openings are arranged to come at convenient points on a line across the crop rows. With field corn an opening every fourth row has been found satisfactory, but every second row is probably more so as little hand work is required. All the irrigating is done by means of furrows and it has been found that permitting the water to run down every other middle between the corn rows gives satisfactory results.

With such a system it has been found that a clay-loam soil with a slope of 3 to 7 feet per 100 feet will absorb 20,000 gallons of sewage per acre per day, for long periods. Uninterrupted disposal on one tract of land is to be avoided however.

Impressive increases in yield of field corn have been obtained consistently for a number of years, and of a few other suitable crops for a lesser period.

Considering human inertia in general, and the undeniable specific fact that crops can be grown under the climatic conditions of the Atlantic coastal states without irrigation, it is rather surprising that irrigation has been developed to the extent it has in that territory. On the other hand, crop production is a gamble against many odds, one of which (the hazard of insufficient moisture) may be eliminated by the application of water at the right time. It is undoubtedly the fact that cultivation costs are increased very little by irrigation that persuades some farmers with money in hand to invest in this improvement as against securing additional acres which would increase cultivation costs. It is also probable that irrigation advancement in this territory is likely to be more impressive when speculative increases in value of land are not in immediate prospect. At any rate a growth in irrigated acreage in coastal states has occurred, and the increase in the localities where it has been tried indicates that it has a field of usefulness wherever conditions are suitable and the value of the crops grown will justify the expense involved.

Splits Wood with Gas Engine

A CANADIAN farmer has devised a wood-splitting machine which adds another operation to the long list of duties performed by his gas engine. This machine consists of two old fly-wheels taken from a 5 horsepower engine which had seen better days. The wheels are connected by a heavy shaft. To one is fastened the splitting blade, while the other is used as a belt-pulley.

The axe blade or similar instrument is attached to the fly-wheel by means of two bolts. It extends out just far enough to split the end of a sizable block of wood, held within its reach and steadied on a resting block.

A $1\frac{1}{2}$ horsepower engine has plenty of power to split ordinary cordwood, and from 200 to 250 r.p.m. is considered the best speed at which to run the blade wheel. Both the engine and the splitting mechanism are mounted on a heavy wooden frame, so that they can be moved into the wood pile with a crowbar as the pile is diminished. The inventor of this device estimates that two men can split as much wood in an hour as they could in three days with axes.

Drainage by Pumping from Wells¹

By Walter W. Weir²

DRAINAGE conditions in the arid and semi-arid regions of the United States differ in two important respects from those in the more humid regions. These two differences are so fundamental as to materially alter the methods employed in reclamation. It can no longer be said that the drainage engineer in the West does not fully appreciate these peculiarities; in fact, they have become so fixed in his mind that they are accepted as a matter of course. These conditions are, first, that the water which must be removed in order to affect reclamation comes from below and is a part of the permanent water table of the region. It makes no difference whether the original source of water is from overirrigation on the land itself or seepage losses from nearby or distant canals; the effect is the same and the excess has gone to raise the ground water table. The second condition is that there are present in many of our arid soils alkali salts which, when concentrated at or near the surface, may be destructive to crops.

It hardly seems necessary to more than refer to the successive steps that have been gone through in arriving at a proper conception of this principle and to appreciate the importance of alkali in the reclamation problem. As soon as a full appreciation of these facts was obtained, reclamation of wet lands in irrigated regions began to be successful, and I do not think that it can any longer be said that we do not know how to drain irrigated lands. Any good rule, of course, has its exceptions, and it is these exceptions which keep the drainage field interesting.

It is my purpose, however, to discuss in this paper in some detail only one method of drainage which I think is peculiar to irrigated regions and which is dependent for its success entirely upon the first principle which I have just mentioned; namely, that the water which must be removed by drainage is an intimate part of the normal underground waters. I refer to pumping from wells.

Agricultural engineers in the drainage field have made no greater contribution to science and to agriculture than through the development within the past few years of this method. It must not be assumed that all drainage problems in irrigated regions can be solved by the instal-

lation of a few pumps, or that even in those areas where pumping may be successful that all of the problems have been solved. It is certainly true, however, that more real drainage in irrigated regions has been accomplished in the last decade than was accomplished in the three of four decades preceding.

It was just ten years ago this summer that the first comprehensive system of drainage by pumping from wells was undertaken in the Salt River Valley of Arizona. Here, as also in the San Joaquin Valley of California, and in many other regions, open ditches and tile drains had absolutely failed to accomplish their purpose, although the best engineering minds in the country had assisted in planning them.

It has been nearly two decades ago that drainage engineers began to fully appreciate that the earlier failures in drainage were due largely to the fact that the water table had not been kept low enough. As a consequence drains 12 to 15 feet in depth were dug at a tremendous cost, but, in many instances, with a flow of only 1 or 2 feet in the bottom of these deep drains the water table stood within 3 or 4 feet of the surface only a short distance away. The reason for this was that the water which was being removed was only the top of a continuous water table possibly two or three hundred or more feet in thickness which was under sufficient pressure to cause a vertical movement considerably in excess of the lateral movement to the drains. In the report of the Committee on Drainage of Irrigated Lands of the American Society of Agricultural Engineers made two ago the development of the deep drain idea was adequately presented to the Society and it will not be further discussed here.

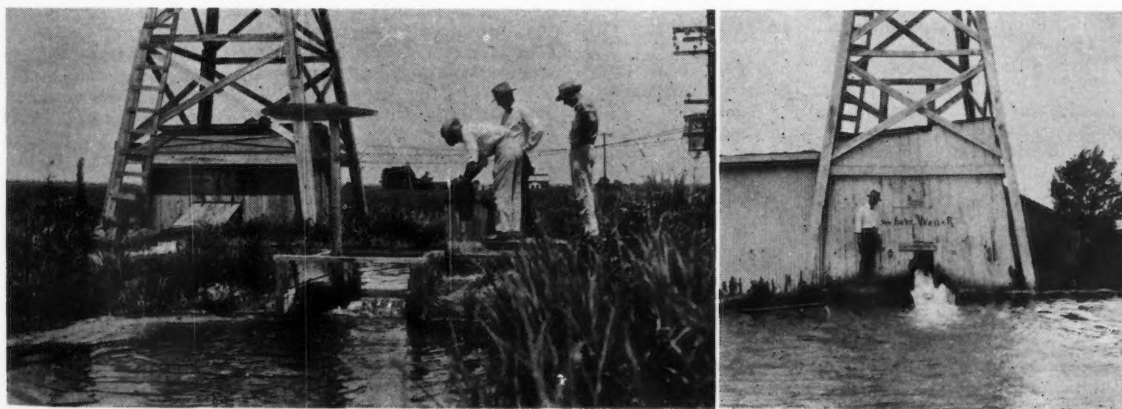
The drainage wells and pumping plants which were installed in the Salt River Valley, first more or less experimentally, proved successful beyond fondest hopes of their engineers. It was known beforehand that water was obtainable by pumping from this region and if the scheme had not proven successful as a drainage measure the expenditure would not have been in vain since the water could be used, and was needed, for irrigation.

As a result of this original work in Arizona, pumping for drainage has been developed into possibly the major method now employed in the West and examples can be found in every western state.

One may confidently expect to get beneficial results from wells in any locality where irrigation water is available by pumping, unless perchance there is some im-

¹Paper presented at the 23rd annual meeting of the American Society of Agricultural Engineers at Dallas, Texas, June, 1929.

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(Left) Rice irrigation with water pumped from wells. Overirrigation seldom occurs where the supply comes from underground sources. (Right) Pumping plant near Stuttgart, Arkansas, where the water is used for the irrigation of rice

pervious layer of material between the surface and the supply of such water. We have now come to believe that such unfavorable conditions are far less prevalent than was thought to be the case some years ago. Pumping from wells has lowered the water table in certain areas where it was not even considered as a possibility a short time ago.

Location of Pumping Units. This method of drainage has more flexibility in the location of the various units than any other. With tile and ditch work it is essential that the drains be located in the wet areas, but with pumping where the success is dependent on lowering the general, rather than a local, water table, the individual units or pumping plants may, when it is more convenient to do so, be located outside of the wet areas. When a pump discharges into an open drainage ditch it will usually be located in the lowest place, but when, as is usually the case, the discharge is into an irrigation canal, the pumping unit may be located near the canal even though it is as much as a half mile from the wet area and on much higher ground. The nearer that the pump is located to the area to be drained the quicker will be the response and the more advantage is gained from the drawdown cone surrounding the well, but this advantage may be entirely overcome by the disadvantage of pumping through a long discharge line. The total pumping head may not be materially different in the two cases. There is also an advantage in locating a pumping plant near a road because of greater accessibility.

Aside from these details in location, pumping plants may be placed so as to function as individual plants, where it is not intended to drain the land midway between them, or they may be placed so as to function collectively where each pump assists in the general lowering of the water table. Pumping plants may also be located in one or more lines across the general slope so as to act as an intercepting drain.

As illustrations of this procedure, in the Salt River Valley west of Phoenix there are two approximately parallel lines running east and west with pumping plants conveniently located at section corners which intercept seepage from one of the main irrigation canals. North of Phoenix the wells are bunched in a smaller area, not so regularly spaced nor so conveniently located. Here they are intended for intensive pumping from a more limited but wetter area. Again, south of Mesa, wells are located at every section corner over an area 4 miles wide and 5 miles long where a more general lowering of the water table over the entire area is desired. At Turlock in California small pumping units are placed in irregularly spaced, not too convenient locations, where each one has a particular and more or less independent duty to perform. In the Pioneer District in Idaho the same idea is carried out except that each plant has a larger area to drain. In the latter district one well delivering a little under 6 cubic feet per second drains about 1100 acres with a total pumping head of only 37 feet.

Size and Depth of Well. The depth and size of drainage wells differ greatly for different localities, but are generally nearly uniform within the locality. Experience teaches that for a given area a rather uniform soil profile or well log can be expected and that similar wells will produce similar results; in any other locality, however, the soil profile will be so different that entirely different results will be obtained. On the other hand, in the San Joaquin Valley it has been possible to design a well to meet almost any predetermined need and the judgment of the engineer as well as his personal ideas on the most satisfactory procedure has been a determining factor.

In Arizona most of the wells are 18 inches in diameter and since a large capacity well was desired, the depth was only in part determined by the strata encountered. Within a reasonable limit of drawdown each well is pumped to its capacity.

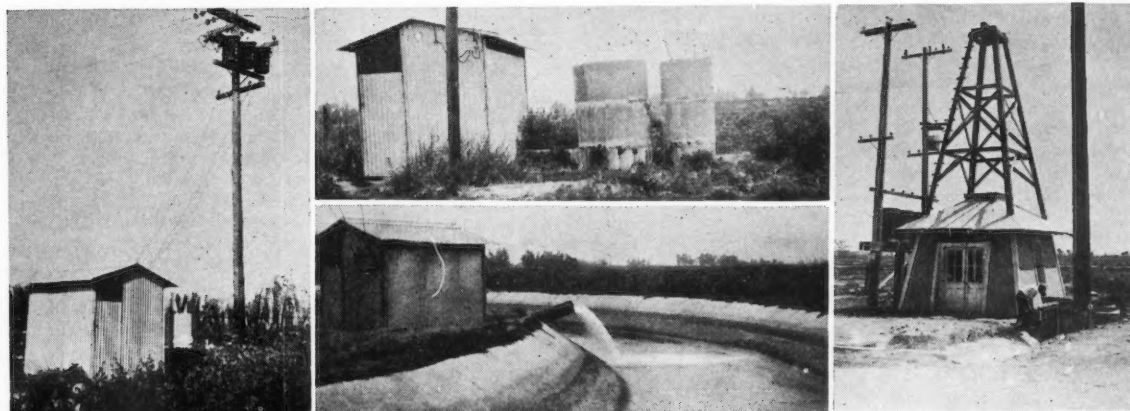
There is a greater variation in the depth of wells in Salt River than any other region; they range from about

150 feet to more than 2000 feet. The average, however, is probably about 225 feet in depth. Many of the San Joaquin Valley wells are 24 inches in diameter, although probably the 16 and 18-inch size are more common. Water can be secured at from 60 to 225 or more feet in this valley and most of these wells are under 200 feet in depth with a considerable portion of those in the Turlock District averaging around 100 to 125 feet in depth. It is not absolutely essential that gravel or coarse sand be encountered in the soil profile for a drainage well to be satisfactory, but such a condition is highly desirable and as a consequence an effort is made to construct a well deep enough to encounter such material.

While on the subject of well logs I would like to mention briefly a very fine piece of work that has just been done by the Well Drilling Contractors Committee of the Western Irrigation Equipment Association. This association is made up of materials men and others interested in irrigation equipment in California. Among its members are a number of well drillers who for years have been working under various contracts with those for whom they drill wells and the whole situation was very unsatisfactory both for the owner and the well driller. This committee, has completed a contract which has been adopted by the association, and I believe will be used in the future not only by the drillers who are members of the association but by all drillers. One contractor working under this contract is providing his employer with a permanently framed and glass-covered record showing all of the details of the well as delivered by the driller. It does not take a very active imagination to see the advantage of preserving an accurate record of well logs.

Well Casings. The kind and type of casing which is being used in drainage wells has been the source of considerable difficulty. Probably no one factor has caused as many failures in wells as has that of putting in the wrong type of casing. If I seem to stress this point unduly it is because it is of particular importance and one upon which I think some investigational work might well be done.

There are three general types of casing used: (1) The California or stove pipe casing, (2) the screw casing with strainer, and (3) the gravel envelope and stove pipe casing combined. The first of these is very generally used in California for drainage wells, but I believe it only has one particular point in its favor and that is its cheapness. The stove pipe casing may be used with considerable success and safety where the water-bearing strata are gravel, but under other conditions I believe other types of casings would prove to be more desirable. This casing consists of short lengths of 10 or 12-gage steel pipe which fit together like a stove pipe and are used in either single or double thickness. With the double thickness casing the outside wall is naturally slightly larger than the inside and they are put together so that the joints are staggered. This casing is placed during the drilling process and usually follows only a short distance behind the drill. The bottom of the casing rests on a narrow shelf at the top of the last solid strata encountered. This leaves an open-bottomed well with the drill hole through the last strata uncased. Sometimes the casing is perforated at all of the water-bearing strata, and at other times it is not perforated at all and the entire flow enters at the bottom. Perforations are made by an especially made perforating tool after the drilling is completed and the casing is in place. The troubles that have occurred with this casing are due to collapsing, under the strain of side pressure, settling due to undermining and collapse of the shelf on which it rests, and to imperfect or unsatisfactory perforating. In wells where the main water supply comes from sand at the bottom of the well and the overlying shelf on which the casing rests is only a few feet or even inches in thickness settling is quite likely to occur. I have seen many wells from which a carload or two of sand have been pumped. This must



(Left) Drainage pumping plant in San Joaquin Valley, California. They are usually small outfits pumping about 1500 gallons per minute, but operating continuously for about eight months each year. (Upper middle) Drainage pumps frequently discharge into concrete pipe lines and the water is used for irrigation. (Lower middle) Pumping drainage water into an irrigation canal serves a twofold purpose, it obviates necessity for expensive outlets and puts the water where it can be readily reused. (Right) The typical drainage pumping plant in Salt River Valley, Arizona

certainly leave a considerable cavity at the bottom of the well, and if under the strain of heavy pumping, the roof of the cavity gives way, the well is ruined. The stove pipe casing can not be removed from a well after it has been placed, and in case the well proves unsatisfactory for any reason the casing is lost.

Often where water is found in sand throughout any considerable part of the drill hole, the gravel envelope casing is employed. This consists of drilling a large hole which is temporarily cased with a screw casing. Inside of this is placed a smaller perforated casing of the stove pipe type and the space between the two is filled with selected gravel. The outer casing is then removed. As the well is developed and sand is pumped out more gravel is added until there is no more movement of sand. This makes a very satisfactory type of casing and gives a well which usually is a good producer.

The screw casing is more familiar to engineers outside of the western states and needs but little explanation. This casing is placed after the well is drilled and is perforated before installation at points determined by the well log. The casing is made of much heavier material and usually has a strainer on the bottom. This casing, however, is more expensive and unless adequately perforated does not always permit of such large capacity wells as do the other types of casings.

It takes experience in a given locality before it is safe to decide upon the most desirable type of casing to use. In a recent report on pumping for drainage in Idaho it is stated that several wells using the open-bottom, California stove pipe casing have failed and that either the gravel envelope type or a modification of it with the so-called Layne shutter screen has been found necessary under their conditions.

Kinds of Pumps. The next thing to consider is the pump. Although there is a wide choice in the make of pump and a wider choice in sizes, the general principles of the drainage pump are similar. With the proper sized pump determined, it is not important except in particular cases what kind or what make is used. The pump manufacturers have been of great assistance to us in the matter of pumps. The Western Irrigation Equipment Association, which I have already mentioned, has been cooperating wonderfully with the users of pumps both for irrigation and drainage.

While the well is being developed to remove sand and produce a constant flow, it is a relatively simple matter to determine the quantity of water which that particular well should produce and the head against which

it will be required to pump. With this information at hand, and the size of the well specified, the manufacturer can produce a highly efficient unit with the number of bowls, speed of motor, and horsepower all worked out and tested. The deep-well turbine with direct-connected vertical motor is almost universally recognized as the most satisfactory drainage pump, and only in rare instances are other types considered. Different makers have their own trade names for certain pumps, but the general principles are alike.

The performance of the individual well under test is the basis for determining the size of pump to be used, but fortunately every well is not different from every other well. In many localities a well of given size and depth can be depended upon, within reasonable limits, to deliver the same amount of water as other wells under similar pumping conditions, and for that reason you will find many outfits which are exact duplicates. This conclusion was reached, however, only after considerable experience in the locality. In a new locality or one in which it has not been proven that similar conditions can be expected for similar size and depth of well, it is certainly unwise to order a pump before the well has been tested. A drainage pump differs in one essential from a pump which is primarily for irrigation. For irrigation either a definite quantity of water is required regardless of drawdown, or the well is pumped to capacity at what has been previously determined was an economic drawdown. In the drainage well, drawdown is the essential thing; one must have sufficient drawdown to afford drainage, and enough water is pumped, whatever that quantity is, to get this drawdown. This, however, does not in any sense mean that in different localities and under different conditions similar drawdowns will produce similar drainage. In general the most satisfactory drainage well is one which produces a larger quantity of water and at the same time causes the water to lower considerably below its original plane. Drainage pumps may be found which will produce as high as 10 cubic feet per second, while others are successful with less than 2 cubic feet per second. Some wells might be pumped dry—in other words, a complete drawdown—and yet not be satisfactory as a drainage well because it does not produce enough water.

I have already mentioned that the manufacturers of pumps need know only the quantity of water to be pumped and the head against which it is to be pumped, and they can design a highly efficient outfit for the purpose. Pump efficiencies of 75 to 80 per cent which can be maintained under almost constant use for several years are obtain-

able. There are many outfits in which the plant efficiency is more than 60 per cent.

Maintenance of Pumps. Aside from being efficient these plants are very nearly foolproof and require very little attention. They are expected to operate continuously for long periods, sometimes 8 or 9 months a year. The most serious thing that can happen is interrupted power. If the interruption is for only a few seconds, a sudden application of power might cause trouble if the back flow from a long discharge line runs the pump backwards. Automatic time delays are usually provided so that sufficient time elapses for the pump to actually come to a stop. These time delays are also regulated so that only a few of the pumps on a big system are started at the same time. The usual custom is for the operator to visit the pump once each day, but they are often left for several days without any injury. One attendant can take care of 30 or 40 pumps if they are located so as to be accessible by automobile. The attendance necessary for the modern electrically operated drainage pump is very small and consists of but little more than regular oiling.

Effectiveness of Pumping. The final test of any drainage system is whether or not it actually drains the land and like all other types of drainage, pumping produces variable results. There are undoubtedly many places, in the irrigated regions, where this method is not at all feasible and no beneficial results could be obtained from pumping. Pumping has, however, proven wonderfully efficient in many places where other methods have failed.

As I have already mentioned, drainage pumps are sometimes intended to function as individual units and to drain a specific area and again they are intended to function collectively and no particular area can be said to be drained by a particular pump.

About 5 years ago a single drainage pump was installed by the University of California on its own property near Fresno. This has operated continuously during the irrigation season since then and somewhat intermittently at other times. There are no other drainage pumps in the vicinity and this one can certainly be considered as a complete unit. This pump discharges about 1500 gallons per minute against a total head of about 25 feet and successfully drains the area within a radius of 2000 feet. This pump is put to a hard test in that it is located on a large area of high water table, and it has been found that the water table will resume its normal height at the pump within less than two days after the pump is stopped. This pump discharges more than 1000 acre-feet annually.

In the Pioneer Irrigation District in Idaho one pump discharging about 5.8 cubic feet per second, or 2600 gallons per minute, drained 1100 acres of land. This pump produced 1750 acre-feet of water in about 5 months of continuous operation. Another pump discharging 2000 gallons per minute yielded 1300 acre-feet in 5 months and drained 700 acres of land.

The Turlock Irrigation District is discharging through 66 drainage pumps more than 50,000 acre-feet of water

annually and the Merced Irrigation District about the same amount. At Fresno 7 drainage pumps with an average discharge of 2500 gallons per minute have with some intermittent assistance from privately owned pumps completely drained this area which at one time was the most poorly drained in the San Joaquin Valley.

There are many instances where drainage by pumping from wells has been very successful and new installations are going in all the time. The encouraging part about it is that the new installations are being placed not only in proven areas but in areas where engineers have heretofore had some hesitancy in recommending this method.

The drainage water which is developed in this way is discharged either into open drainage canals and is wasted, or is turned back onto the land as irrigation water. The latter use is the most common for pumped water but seldom used for the discharge from other types of drains. There are several advantages to this method, one of which is saving the cost of outlet drains as the irrigation canals are already constructed and no additional expense is involved.

Costs. Drainage by pumping has not proven expensive, at least as compared to other methods of drainage for irrigated lands. There are two costs to be considered: First, the installation cost of putting down the well and equipping it with pump, motor, housing and discharge lines, as well as bringing in the power lines, and, second, the cost of operation and maintenance. The installation cost varies with the size of the unit from about \$1200 for the smaller outfits to nearly ten times this amount for some of the largest. I do not think it necessary to go into detail as to how this cost is made up.

Twelve hundred dollars will construct only about $\frac{1}{4}$ mile of drainage ditch or outlet tile line and \$1200 will construct not much more than two miles of drain such as is necessary for our conditions of depth. This much drain in itself would be absolutely useless in most areas.

The operation cost might at first thought be considered as a very important factor and one which would greatly influence the choice in determining the type of drainage to install. This, however, is not the case. Electric power is used exclusively and in most western states is rather cheap. In California it costs about 2 cents to raise one acre-foot of water one foot in height which means that drainage water costs from about 50 cents to \$1 per acre-foot. In terms of gravity flow the operation and maintenance will cost from \$1 to \$2 per day for each cubic foot per second of flow. The lower figure is more nearly the correct one as very few drainage pumps have a lift of 50 feet, such as would be required to run the cost to the larger figure. Take, for example, the pump already referred to as belonging to the Pioneer Irrigation District; last year it cost 55.5 cents per acre-foot of water pumped or about 88 cents per acre per year for the area drained.

Nearly all pumped drainage water is used for irrigation and as such has considerable value. Even in areas of

This is the author, Mr. Weir, himself. With reference to this particular picture his comment is this: "The best practice in both drainage and irrigation calls for accurate knowledge of the amount of water being used"



ample water obtained from gravity flow water is worth \$1 per acre-foot. The average cost of pumped drainage is only about one-half of this amount. A very interesting situation has arisen in the Modesto Irrigation District. There has been recently completed a large storage reservoir in this district providing ample water for irrigation. This district generates its own power as a by-product. It has been found that one acre-foot of water at the reservoir will pump 3 acre feet of drainage. In other words, the water is worth three times as much for power as it costs to pump drainage water. Needless to say this district no longer has a drainage problem. It is saving the stored water to generate power to pump irrigation water from the land which needs drainage. Salt River Valley in Arizona is doing the same thing; what was once a serious drainage problem has become an irrigation asset. In only a few instances has pumped drainage water been found to be chemically unfit for irrigation.

In the Salt River Valley where the longest records of pumping are available, there are now installed about 100 individual plants with a total annual discharge of approximately 160,000 acre-feet. This has cost very close to 40 cents per acre-foot for operation and maintenance, or a total cost including overhead and depreciation of about 75 cents per acre-foot. Reduced to an acreage basis this makes the cost about \$2.80 per acre per year for the 64,000 acres which required drainage. As a matter of fact, the cost was actually spread over the entire project and amounts to less than 90 cents per acre. This, of course, does not include any resale value to the water pumped. These costs for the Salt River Valley are not

out of keeping with those for other pumped areas, and if the water were all wasted, as is usually the case with drainage water, the cost per acre would be very reasonable. Water at 90 cents per acre-foot is the cheapest water that a district can use for irrigation. It is less than the cost of the cheapest gravity water in California and probably about one-third of the cost of most so-called cheap gravity supplies. Some of the more expensive pumped irrigation supplies cost \$10 to \$20 per acre-foot. A low cost of drainage water per unit of discharge and a low cost per acre for drainage are indeed very desirable, but efficient drainage from the standpoint of actual results accomplished is the most essential thing. There can be no question as to the benefits which are being derived to lands drained in this way and when one can get excellent results and low cost at the same time it is indeed a happy situation. This is exactly what is being accomplished.

With the use to which the drainage water is put and its value for irrigation even in regions of abundant water, it is evident that this type of drainage is economical and the only cost, except such as are made for bookkeeping records, is the first cost of installation plus the cost of what little off-season pumping is done. From the experiences of the past ten years it would appear that a great forward step has been made in drainage of irrigated lands. Certainly there has been much more land reclaimed than has become waterlogged, and in many places the drainage problem can not be looked upon as a fundamental weakness in agriculture under irrigation.

Utilization of Agricultural Wastes

THE increasingly important services which the U. S. D. A. Bureau of Chemistry and Soils performs for producers and consumers of farm products and for those who manufacture such products into articles of commerce, is discussed by Dr. Henry G. Knight, chief of the bureau, in the report of the work of the bureau for the fiscal year ended June 30.

In the year the Bureau of Chemistry and Soils, under which have now been combined the activities of the former Bureau of Chemistry, the former Bureau of Soils, and the Fertilizer and Fixed Nitrogen Laboratory, actively prosecuted investigations and research under 122 main lines of work. These range from the soil survey, which up to now has mapped and inventoried the soil resources of more than half the agricultural land of the United States, and the closely related fields of soil chemistry, soil physics, soil microbiology, soil fertility and soil erosion, through the work of taking nitrogen—a fertilizer element—out of the air, investigations of potash and phosphate resources, crop chemistry, fruit and vegetable chemistry, the production of organic acids by fermentation methods, the utilization of farm and industrial wastes, naval stores, food microbiology, food deterioration and spoilage, prevention of dust explosions and farm fires, to improvements in the technic of producing sugars, vegetable oils, proteins, insecticides, fungicides, tanning materials, and a variety of other products.

Widening of markets, better prices for various farm products, and the development of new lines of industry for manufacturers, are objectives which the bureau is striving for in its work on the utilization of farm and industrial wastes, work which was outstanding among the bureaus' activities in the year. The use of cornstalks for the making of paper and fiber board has been carefully investigated by the bureau, which has demonstrated a paper containing cornstalk pulp which has a greater bursting strength and folding endurance than standard newsprint paper, though in the present stages of development of the two, the latter is more opaque and has better printing qualities. The report states that good fiber board is

being manufactured from cornstalks with fair prospects of financial success.

Attacking the problem of lignin, one of the three great components of agricultural wastes, which comprises 30 per cent of the dry material of all vegetation and is wasted at the rate of approximately 40,000,000 tons a year, chemists of the bureau have found that among the products of dry distillation of lignin are eugenol and gulacol which are products of distinct value in the drug field and possibly in the industrial field.

Looking to a profitable utilization of the great quantities of sweet potato culls wasted every year in the Southern States, the bureau has made studies of sweet potato starch which indicate that this starch compares well with Irish-potato starch, and in cooperation with a sweet potato starch factory, the first to be established in the United States, has gained useful information regarding possible uses for sweet potato culls.

"Cane cream," a new product developed by the bureau from cane sirup made from low-purity juices, is now being produced commercially. Experiments made by the bureau indicate that better grades of molasses may be produced by methods of clarification of juice without reducing the sugar yield. Enlargement of the markets for the products of American sugarcane planters should result from these findings.

Following the recent provision of funds by Congress for study of the prevention of soil impairment by erosion, a reconnaissance survey has been in progress for the purpose of locating and outlining the boundaries of the severely eroded areas in the United States. As a result of this survey, 18 districts have been recognized in which soil impairment by erosion has become serious, and plans have been made to establish in each of these areas a field station at which erosion and moisture conservation problems can be studied. This important program of erosion prevention is largely an outgrowth of the soil survey work of the Bureau of Chemistry and Soils, which has for many years described and mapped those soils which are subject to severe washing and erosion.

Rice Irrigation on the Grand Prairie of Arkansas¹

By B. S. Clayton²

THE Grand Prairie of Arkansas is located in Prairie, Lonoke, and Arkansas Counties and comprises a section of open country located west of the White River and extending from the timbered land just north of the Rock Island Railroad to a point near the junction of the White and Arkansas Rivers. The open spaces are broken by the wooded stretches along the streams and by small isolated bodies of timber locally known as islands. The northern end of this area is about 235 feet above sea level and the general slope is about a foot per mile from north to south. The prairie was originally covered with wild hay. Cattle raising was the important industry, also a considerable quantity of this hay was cut and shipped to market. The sub-soil is a hardpan or tight clay which is largely impervious to water and it is this characteristic together with the level topography, which makes the region especially adapted to rice culture.

The first rice was raised about 1904, but several years elapsed before the fact was generally appreciated that rice could be made a profitable crop. The development then continued rapidly, and with the added impetus of war prices reached a maximum in 1920. During the past few years the acreage planted to rice has steadily declined due both to lower prices and decreased yields per acre. The sod land, as it was called, when first planted to rice, yielded 80 to 90 bushels per acre, but these high yields rapidly declined after the first few seasons of cultivation. Arkansas produces about one-fifth of the total rice crop of the United States and about 80 per cent of the state crop is grown on the Grand Prairie. The 1928 crop in this portion of the state covered 131,000 acres; the average yield was about 42 bushels; and the average price about 85 cents per bushel.

Source of Water Supply. The water used to irrigate the rice is secured almost entirely from wells. The first water bearing stratum, which is from 20 to 40 feet thick, rests upon a bed of hard clay from 100 to 140 feet below the surface. The material varies from coarse gravel to fine sand. Beneath this stream and at a depth of 700

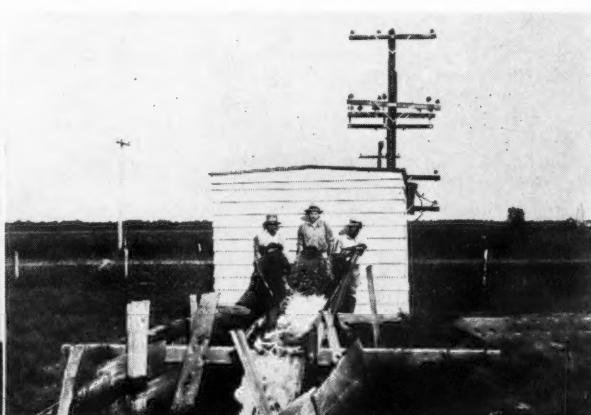
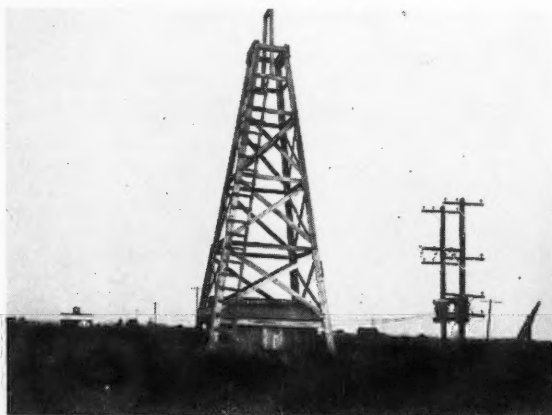
to 900 feet is a second water-bearing stratum into which a few wells have been driven. It has been observed that the static water level in the wells drilled to the first stratum has lowered from one to two feet per year. This has decreased the flow of water and increased the cost of pumping and caused some anxiety as to the permanence of the water supply.

The ground water division of the U. S. Geological Survey is now making an investigation to determine the rate of fall of the static water level and the amount and source of the recharge waters. At the beginning of the 1928 pumping season there were approximately 1400 wells in the Grand Prairie. These varied in flow from about 400 to 3500 gallons per minute and average probably between 750 and 800 gallons.

Prime Movers. The early pumping plants were all driven by steam engines using wood as a fuel. A few of these plants are still in operation. The steam power was gradually superseded by the semi-Diesel, two-cycle oil engine. These engines are of the hot ball type and are started by heating the walls of the combustion chamber with a blow torch to secure the initial explosion. The operation of the engine then keeps the walls of this bulb sufficiently hot to ignite the fuel when sprayed in. The engine speeds vary from 250 to 300 revolutions per minute and the sizes commonly used are 50 to 100 horsepower. The fuel consumption is from 0.50 to 0.75 pounds per brake horsepower.

During the past season some high-speed, direct-connected, two-cycle engines were placed in use. These engines start with compressed air from a separate tank; thereafter the heat developed as the piston compresses the new charge of air is sufficient to ignite the fuel oil sprayed in at the end of the stroke. The air pressure in the combustion chamber reaches 500 pounds per square inch, and the speed of the engine is about 800 revolutions per minute. It is a marine type of engine, previously used on dredging work, and is expected to operate with less attention than is required by the usual type of engine.

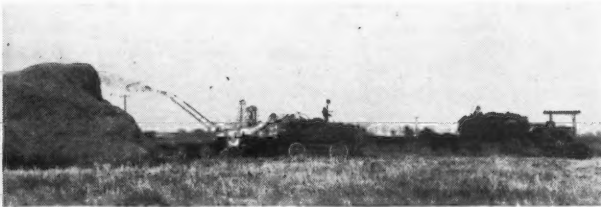
Beginning a few years back the number of electric motors used to operate pumps has steadily increased. During the 1928 season 280 plants, or about one-fifth the total number, were driven by motors. So far during the



(Left) View of typical motor-driven pumping plant on the Tallman Farm near Stuttgart, Arkansas. The mean flow at this well was 525 gallons per minute. (Right) The motor-driven pumping plant on the Rice Branch Experiment Station near Stuttgart. The flow of this well is about 800 gallons per minute

¹Paper presented at the 23rd annual meeting of the American Society of Agricultural Engineers at Dallas, Texas, June, 1929.

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(Left) A typical rice-harvest scene on the Ed. Bull farm near Stuttgart, Arkansas. (Right) Threshing rice on the Hedrick farm in the same locality

present season about 70 new motors have been installed and the great majority of these are 25 or 30 horsepower. No new engines have been sold this season but several second-hand ones have been installed at new wells. If the present tendency continues, the electric motor will in the next ten years almost entirely supplant the oil engine as the source of power in this field.

The motors here used are mainly of the squirrel-cage, induction type, and the more recent installations are known as "line starters." These have a high resistance winding which prevents an excessive current flow when starting. The efficiency of the motor is usually 90 per cent. The electric power used in this field is three phase, 60 cycle, reduced from 13,000 to 220 volts in the transformers at the pumping plants.

The minimum rate for power during the past season was \$4.00 a month per horsepower installed. This entitled the consumer to use 100 kilowatt-hours per rated horsepower and any additional current used during the month cost 1.5 cents per kilowatt-hour. It is estimated that the average rate for current at the 280 plants for the 1928 season was 2.2 cents per kilowatt-hour and that for a season of normal rainfall the average cost would be 2 cents per kilowatt-hour as the total amount of current used would then be greater.

Pumps. The pumps are of the deep-well turbine centrifugal type usually made with from two to four bowls or stages. The static lifts near Stuttgart, in the center of the rice area, vary from about 100 to 130 feet. The usual operating speed of the pumps when engine driven is 800 to 900 r.p.m., and this speed can be varied by changing the size of the pulley on the pump head. At the motor-driven plants the speed of the pump and motor is the same as they are direct connected. Some of the first motor-driven pumps operated at 860 r.p.m., later 1160 r.p.m. was used. Practically all the pumps installed during the past two years operate at 1760 r.p.m. The change to the higher speeds has been largely due to competition between the pump manufacturers, as the high speed pumps can be made with fewer stages and less weight and can therefore be sold cheaper.

Wells. There are few wells of uniform diameter used in this field. Practically all the wells consist of a pit 18 to 26 inches in diameter extending down to the water-bearing stratum, and from this point the blank pipe and screen extend through the water-bearing sands to the clay beneath. The blank pipe extends five feet or more above the bottom of the pit and on this the pump is seated and sealed. The seal is considered necessary for the best performance of a well located in the sand formations. There is a difference of opinion as to its effect under certain conditions, but it is well established that it prevents sand heaving up into the pit and thence into the well when the pump is started; and it is also a fact that the flow of a sealed well can often be increased by starting and stopping the pump, thereby causing a surge of water back through the screen and sands. The space between the pit and well casing is often used as a magazine to hold fine gravel which falls into the cavity formed when sand is pumped through the screen. The gravel prevents the caving of the clay above, and also tends to increase the flow of the well.

The screens are usually 15 to 25 feet in length, depending on the thickness of the water-bearing strata. A large number of wells use a screen $1\frac{1}{2}$ inches inside diameter. The present tendency is to make the well of large size and pump it at a rate less than its capacity, which prolongs the life of the well.

In the vicinity of Stuttgart the wells are from 120 to 140 feet deep; the static water level is about 80 feet below the surface; and the drawdown is from 20 to 40 feet depending on the nature of the stratum and the rate of pumping. In some wells the entire weight of the pump rests upon the seal, but in the great majority of cases most of the weight is suspended from the top of the pit. There are a few wells in this field that have been in service for 20 years, but the average useful life of a well is 10 years. Corroding of the openings in the screens and caving in on account of pumping sand are the usual causes for the loss of a well.

There are a few deep wells in this field which draw water from a stratum 700 to 900 feet below the surface. The pumps in these wells are set at such depths that water is at all times above the bowls and no suction lift is required. The water from this depth has a temperature of 75 degrees and is about 10 degrees warmer than that from the ordinary wells. As the deep wells are rather expensive, costing about \$10.00 a foot, it is not probable that many will be drilled under present economic conditions in the rice belt.

Duty of Water. During the 1928 season a record was kept of the total depth of water pumped on seven fields of rice varying in area from 94 to 203 acres. At six plants the water was measured with standard rectangular weirs and at the seventh a Venturi flume was used. The quantity of water used on ten special plots at the Rice Branch Experiment Station was also measured. A record was kept of the rainfall during the irrigating season and up to the time the levees were cut to drain the fields for harvest.

The amount of water pumped varied in depth from 13.1 to 18.0 inches; the rainfall varied from 13.6 to 18.8 inches; and the total water used from 30.5 to 35.1 inches. The amount of water used depends somewhat on whether the crop is an early or late variety of rice. The smaller amounts of water were used on fields where the crop was all or largely of the early varieties. Usually the crop is made up of both an early and a late variety of rice as this arrangement allows more time for the harvest period. The normal rainfall during the summer months is 12 inches and the total time of operation of the pumps during an average season is 70 days, according to the records of the Arkansas Power & Light Company.

Using the above figures it was estimated that a pump should have a capacity of 6 gallons per minute for each acre irrigated. At this rate the total depth pumped during a normal season would be approximately 22 inches, and with the 12 inches of rainfall would provide a total of 34 inches of water on the crop. The total days of pumping will depend on the amount of rainfall and a rate of 6 gallons per acre should provide sufficient water for practically any season. This rate is based on the average discharge of the pump. When the pumps are first started the discharge will be considerably more than the average for a short period. The duty of water here given applies

to the soil of the greater portion of the Grand Prairie; however, in the north end of the prairie, the soil type is more open and is said to require a larger amount of water. During the present season records are being kept at thirteen plants and the results will provide a check on the estimate of duty here given.

Cost of Pumping. Records on the cost of pumping were kept at three motor-driven plants and at five plants operated with oil engines. From the data obtained it was estimated that the total cost of pumping including fixed charges will vary from \$10.00 to \$12.00 per acre. These figures were determined for areas of 80 to 200 acres and static lifts of about 100 feet and apply to an average season. The motor sizes were from 25 to 40 horsepower and the engines from 60 to 85 horsepower.

The fixed charges represent about two-thirds the total cost of operation at the oil engine plants and about one-third that at the motor plants. As far as conclusions could be drawn from the data it appeared that the motor-driven plants were the more economical on the smaller areas up to probably a quarter section in size and that the oil engine plants were the cheaper for the larger areas. Where fixed charges are included there is not a wide difference in the cost of operating the two types of motive power.

Motor-operated plants built during the past two years have cost about \$100 per horsepower installed and represent a capital investment of \$25 to \$30 per acre watered. The present tendency in this field is toward plants of a capacity of 500 to 600 gallons per minute.

The facts presented in this paper are based on an investigation of rice irrigation in Arkansas undertaken jointly by the Division of Agricultural Engineering of the U. S. Department of Agriculture and the College of Agriculture of the University of Arkansas.

DATA FROM 1929 PUMPING SEASON²

The major portion of the rice crop is planted between May 1 and May 20, and the pumps are generally started between May 20 and June 10. They continue in operation more or less continuously until the end of the irrigating season from August 20 to September 20, depending on the variety of rice and date when planted. The irrigating season usually covers from 90 to 100 days and the total average time of operation of the pumps is estimated at 70 days. This time however depends on the amount of rain and the rate of discharge of the well per acre watered. During the past season the thirteen wells under observation varied in total time of operation from 44 to 115 days.

The average amount of rain which falls during the summer months is almost one foot as determined by a 42-year record at Stuttgart. This total may vary from 6 to 18 inches according to the season, and the necessary amount of pumping will depend on the rainfall. Occasionally a heavy rain may cause the levees to break and thus sometimes increase rather than diminish the amount of water pumped. The field levees are commonly located from 0.1 to 0.3 feet apart vertically. The present tendency is to shorten the spacing, thus providing a more uniform depth of water and reducing the size of levees so that they may be more easily crossed with tractors and binders.

A Stillwell and standard rectangular weir were installed at each well, except one, where a Venturi flume was used. An automatic gage recorded the head at each weir or flume, and about three times a week the head was checked by direct measurement with a hook gage. A rain gage was located near each well. On account of the very dry summer of 1929 a number of farms either

sold or bought some water from neighbors. In all such cases the amount though relatively small was measured and corrections made accordingly. At the end of the season a needle and stadia survey was made for each rice field. The results were plotted to a scale of 200 feet to the inch, and the area in rice stubble was determined by planimeter measurement. A tabulation was made showing the daily discharge over each weir in acre-feet, and total hours of operation. From these data the total depth pumped in inches was calculated and to this the rain which fell during the irrigating period was added, giving the total depth of water which was used on the crop.

The summer of 1929 was exceptionally dry. About half the normal amount of rain fell. Only three summers during a 42-year record were drier than this one. If we include the month of May with the summer months there has been only one season which showed less rainfall. Beyond a doubt a dry season is better for securing data on the duty of water than a wet one, for as the supply of water is more abundant, the tendency is to use an excessive amount; also in some cases heavy rains may break the levees making it necessary to pump additional water to reflood the fields.

During the 1929 season records for duty of water were kept on eleven farms. With two exceptions the total water used on nine farms varied from 23.1 inches to 30.3 inches. The total depth of water used on the rice under four wells varied from approximately 23 to 25 inches. This rice was all an early variety. The rice under five other wells was a combination of early and late varieties; here the total depth used varied from about 27 to 30 inches. No water was lost due to levee breaks from heavy rains, and when a field was drained on account of moss or root maggots, the water was in most cases used on an adjoining field; thus a very economical use of water was secured.

These figures indicate that from 24 to 30 inches of water are required to raise a crop of rice, depending in each case on the proportion of early and late varieties, and also to some extent on the number of continuous seasons that the fields have been planted to rice. Continuous planting encourages the growth of water grasses which in turn make necessary a greater depth of water to check their growth.

Aside from the total depth of water required it is of value to know how many acres of rice should be planted under a well of a given flow. A rate of flow of 5 gallons per minute per acre would amount to 0.022 acre-feet per day and in 80 days would produce a depth of 21 inches over an acre. This plus a minimum of 6 inches of rainfall would amount to 27 inches in total depth. A flow of 6 gallons per minute per acre would amount to 0.026 acre-feet per day or about 25 inches in 80 days, and this with 6 inches of rain would make a total of 31 inches. There will be few seasons when the rainfall is less than 6 inches. It therefore seems reasonable to conclude that a well should have a capacity of 5 to 6 gallons per minute for each acre watered, depending on variety of rice and the condition of the land. Where the land is rather level, the subsoil impervious and the water used in an economical manner, a pump capacity of 5 gallons per acre would suffice, but as tenants generally use more water than owners and as many farmers overestimate the mean capacity of their wells this would be too low a figure to recommend for general use. A rate of flow of one cubic foot per second for each 80 acres watered is equivalent to 5.6 gallons per minute and would produce a depth of 24 inches in 80 days. The six inches of rainfall would make the total depth 30 inches, and if the crop were largely late rice the pumping time could be extended to 90 days and thus produce an additional 3 inches of depth. A well flow of one second-foot or 450 gallons per minute for each 80 acres of rice underlain with an impervious subsoil should provide an ample supply of water.

²A subsequent report by Mr. Clayton on his investigations of rice irrigation on the Grand Prairie of Arkansas, based on results obtained from studies made during the 1929 pumping season. This data was presented as a technical paper at the joint meeting of the Southern and Southwest Sections of the American Society of Agricultural Engineers, at Jackson, Miss., February, 1930.

Influence of Drainage on Forest Growth¹

By Paul C. McGrew²

THERE are hundreds of miles of ditches through the peat swamps of northern Minnesota, and as it is not feasible to develop this land for agriculture at this time the question of the effect of these ditches on the existing forest growth is of interest in considering the utilization of such land. Most of the drainage systems have been in operation 10 to 15 years, and it was felt that trees should show stimulation of growth if drainage has benefited the swamp forests. As the problem was both a drainage and forestry problem a cooperative study was made by the following agencies: Department of Drainage and Waters, State of Minnesota; Department of Forestry and Fire Prevention, State of Minnesota; Division of Forestry, University of Minnesota; Division of Agricultural Engineering, University of Minnesota; Bureau of Public Roads, U. S. Department of Agriculture; and Lake States Forest Experiment Station, U. S. Department of Agriculture.

The field work was done in the fall of 1928 by a field party composed of one representative from each of the cooperating agencies.

The studies were conducted in the principal forested swamps which have drainage ditches in Aitken, Beltrami, Carlton, Koochiching, Lake of the Woods and St. Louis Counties in Northern Minnesota. A total of 718 miles of ditches and approximately 144,000 acres of forested swamp were covered by the field party. The growth along the 718 miles of ditches was mapped for $\frac{1}{2}$ mile on either side showing forest type, burned timber land, cultivated land and open swamp of sedge or brush. Twenty-six areas scattered throughout the counties were chosen and studied in detail.

Conduct of Field Work. The procedure in conducting the field studies was, first, to locate a stand of timber where the timber extended from the bank back on both sides in a uniform unbroken stand. After locating such a stand four plots of $\frac{1}{20}$ acre each were laid out, two being near the ditch on either side and two back from the ditch beyond the influence of drainage. In some cases where

the forest growth was suitable on only one side of the ditch, two plots of $\frac{1}{10}$ acre each were used. The distance to which drainage was effective was determined from borings made in representative trees using the Swedish increment borer. The small cores removed by the increment borer were examined from trees near the ditch and at intervals back from the ditch to a point where the growth of the trees, as evidenced by the thickness of the annular rings, showed no significant change following the construction of the drainage system.

After laying out the plots the trees on each plot were counted and the diameters measured. Representative sample trees of varying sizes were cut and the volume measured. Using the sample trees as a standard for volume the total present volume on each plot was calculated. A large number of cores from each plot were measured to determine the present radius of the trees, the radius at time of drainage and the radius at a period of time before drainage equal to that subsequent to drainage. In measuring the cores to determine the radius of a tree at some earlier period the annular rings were counted back to that period and the radius up to that time measured. From the radii of the trees the volume of the stand at the time of drainage and the period before drainage was calculated. The effect of drainage on the tree growth was determined by the difference in the rate of growth for plots near the ditch compared to those back from the ditch and the growth before drainage compared to that following drainage, making allowance for the natural rate of growth of the stand. The borings made at plots and intermediate points were used to show the change in radius growth from the ditch to a point beyond drainage effect.

A profile of the surface of the peat, water table and underlying mineral soil was taken at each of the areas studied to obtain information on the relationship of these factors to forest growth. The peat at each plot was examined and the different layers classified. The mineral soil immediately underlying the peat was also sampled and described.

Forest Types in Swamps. The three principal species of trees growing in the swamps were black spruce, tamarack and cedar. In a few places balsam fir was found in mixtures with either spruce or cedar, but was not dominant. Based on the area covered by the field party, the percentage of each of the above species was black spruce, 51 per cent; tamarack, 36 per cent, and cedar, 13 per cent. In the accompanying illustration is shown a dredged ditch through a stand of black spruce.

Classification of Peat. In the swamps studied trees were found growing on three general types of peat as follows: (1) Sphagnum peat formed from the sphagnum mosses; (2) sedge peat, formed from carex and (3) woody peat formed from woody shrubs and trees. The peat in the swamp is often a mixture of two of the above types.

In many swamps alternate layers of sphagnum and sedge were found, indicating a change in the growing conditions. It was of interest to note that charcoal was found four to six feet below the surface at several places indicating that fires had occurred at distant times in the past. The peat varied from undecomposed to well decomposed, the growth generally being best on the well decomposed peat.

The peat examined varied in depth from a few inches to more than 20 feet. Black spruce and tamarack were found growing on a wide range of depths, while cedar was generally found on the shallow peat.

Character of Peat Influences Tree Species. The character of the peat influences to a large extent the species



A dredged drainage ditch through a stand of black spruce in northern Minnesota

¹Paper presented at a meeting of the Land Reclamation Division of the American Society of Agricultural Engineers at Kansas City, Mo., December 1929. A more technical report by James L. Averell and Paul C. McGrew, entitled "The Reaction of Swamp Forests to Drainage in Northern Minnesota," was published in February 1929 by the Department of Drainage and Waters, State of Minnesota.

²Associate drainage engineer, Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture. Mem. A.S.A.E.

of trees which grow. Black spruce was the only species found growing to any extent on sphagnum peat. The black spruce on sedge, woody sedge or woody peat made better growth than on sphagnum but was usually mixed with one or more of the other species. Tamarack was found growing on sedge and woody sedge peat. Cedar was found on woody sedge and woody peat, the areas having a dominant cover of cedar being on woody peat.

A limited number of acidity tests were made which indicate that black spruce will grow on more acid peat than the other species. It should be noted however that the black spruce on slightly acid peat has a higher rate of growth. The results of these tests are shown in the accompanying table.

Drainage Beneficial to Forest Growth. In all cases where the water table was lowered by drainage the forest growth near the ditch showed increased growth. This increase varied from small amounts to relatively large amounts, the increase usually depending on the effectiveness of drainage and productivity of peat as influenced by origin and degree of decomposition. In an accompanying illustration are shown outstanding examples of the benefits of drainage.

A few locations were found where the natural drainage was evidently excellent before the ditches were constructed and in such cases ditching did not change the growing conditions. Trees at these locations usually showed excellent growth both before and after the ditch was constructed. The fact that drainage was good before the ditch was constructed could usually be determined by lack of water in the ditch or depth to water as compared to other sections of the ditch.

The possibility that the forest growth might be injured by overdrainage was also studied. No place was found where drainage injured forest growth and no tree was found which appeared to have died through overdrainage, although many were found to have died through lack of drainage. This should not be interpreted as meaning that it is impossible to injure swamp trees by overdrainage but rather that the danger of such injury is very remote. Even in the deeper ditches where the water surface in the ditch was 5 to 7 feet below the surface of the peat, the water table in the peat 5 feet from the ditch was seldom more than 2 feet below the surface of the peat, showing how difficult it is to drain the peat.

There have been periods, however, both before and since ditching, when the water table has been lowered a considerable distance below the surface of the peat due to lack of rainfall and high evaporation. Under such conditions the peat will burn readily and the fire hazard is great. There was no evidence that such periods injured the swamp trees, but on the contrary the trees often showed increased growth.

The growth of the trees, in cords per acre per year, appeared to be the best measure of value and was thus used as a basis of comparison in determining the effect of drainage on swamp forest growth. The volume growth before and after drainage was determined on twenty-six widely scattered areas and is shown in the table. The areas are arranged according to the classification of the peat for each of the three swamp species.

The type of peat not only is a factor in determining the species of trees as discussed previously, but is also a factor influencing the growth of the trees. From the table it is seen that the average growth for black spruce on sphagnum peat was 0.12 cord per acre per year before drainage and 0.28 cord after drainage, the increase attributed to drainage being 0.12 cord per acre per year. The average for black spruce growing on sedge, woody sedge and woody peat was 0.26 cord per acre per year before drainage and 0.59 cord after drainage, the increase attributed to drainage being 0.32 cord per acre per year. From these figures it is seen that the growth on sphagnum peat after drainage is about equivalent to the growth on sedge, woody sedge or woody peat in the undrained con-

INFLUENCE OF DRAINAGE ON FOREST GROWTH								
Study Area Number	Peat Classification		Volume Growth, cords per acre per year			Acidity * pH	Distance from ditch to no drainage effect, feet	
	Origin	Degree of decomposition	Before drainage	After drainage	Increase due to drainage		Upper side	Lower side
BLACK SPRUCE								
17	Sphagnum	Undecomposed to slightly decomposed	.09	.19	.08		150	350
1	"	"	.14	.29	.09	4.1 to 4.5 (Very Acid)	600	450
2	"	"	.14	.26	.11	4.6 (Very Acid)	700	400
25	"	"	.08	.42	.32		cut	300
21	"	Partly to well decomposed	.12	.21	.13		300	500
20	"	"	.14	.29	.00		0	0
		Average	.12	.28	.12			
13	Sedge	Partly to well decomposed	.25	.56	.31		300+	Burned
22	"	"	.14	.44	.33	4.3 to 4.8 (Very Acid)	200	600
14	"	"	.16	.58	.40		Burned	300+
24	"	"	.32	.87	.52		100	500+
18 ¹	Woody sedge	"					Burned	200
10	"	"	.10	.35	.14		150	Burned
15	"	"	.23	.40	.16		100	200
12	"	"	.26	.59	.30	6.2 (Slightly Acid)	350	Burned
6	"	"	.33	.75	.17		100	Burned
9	"	"	.29	.73	.52		200	600+
4	Woody	"	.33	.42	.12	6.5 to 6.7 (Slightly Acid)	250	Burned
3	"	"	.39	.62	.53		650	700+
		Average	.26	.59	.32			
TAMARACK								
11	Sedge	Slightly decomposed	.08	.16	.08		250	Burned
26	Woody sedge	Partly to well decomposed	.14	.47	.38	5.6 (Moderately Acid)	200	940+
19 ¹	"	"					300	500
16	"	"	.44	.47	.00		0	cut
		Average	.22	.37	.15			
CEDAR								
8	Woody	Partly to well decomposed	.16	.43	.23		400	400
3 ²	"	"	.39	.82	.53	6.5 to 6.7 (Slightly Acid)	200	600
7	"	"	.36	.77	.53		300	Burned
25	"	"	.32	.52	.33		100	Dead tamarack
23	"	"	.29	.55	.20		150	Burned
		Average	.31	.62	.36	Average Dist.	252	444

¹ Volume at time of drainage too small to be comparable.
² Large volume, both cedar and black spruce.
³ Increase computed as difference between volume growth before and after drainage, plus or minus the net decrease or increase in annual growth of stand.
* Determined by Division of Soils, University of Minnesota.

¹ Volume at time of drainage too small to be comparable.

² Large volume, both cedar and black spruce.

³ Increase computed as difference between volume growth before and after drainage, plus or minus the natural decrease or increase in annual growth of stand.

* Determined by Division of Soils, University of Minnesota.

dition and about half the growth on the latter in the drained condition. The increase in growth due to drainage of sedge, woody sedge and woody peat is greater than the total growth on drained sphagnum peat. From this it is evident that the sphagnum peat is least productive in both the drained and undrained condition and therefore the least desirable so far as forest production is concerned. The volumes given in cords are total tree volumes including tip, stump and bark and are thus high when commercial volume is considered. On the other hand, the response to drainage did not take place immediately, but on the average after about three years and as this period is included in the 10 to 15-year period for average increased growth, the outlook for the future is somewhat better.

It was difficult to obtain suitable areas for studying the tamarack on account of the serious injury to this species by the larch sawfly. The plots chosen are as free from insect injury as any found but even in these the insect injury probably reduced the growth considerably. There was not the slightest doubt however but that drainage was just as beneficial to this species as the other species.

The average results for cedar were slightly higher than for black spruce on the more productive peat, the average growth being 0.31 cord per acre per year before drainage, 0.62 cord after drainage and an average increase of 0.36 cord per acre per year, allowing for the natural growth as determined from the undrained plots.

Extent of Drainage Effect. Many of the drainage ditches are constructed approximately along the contour instead of directly down the slope. The side from which the natural movement of water comes is called the upper side and the other side the lower side. The ditches constructed in this manner cut off the flow of water to the lower side and, when the natural flow of water on the lower side is such as will continue to flow away from the ditch, drainage is likely to be effective for a considerable distance. Areas 9, 24 and 26 in the table are examples; the drainage influence extended much further than the distances given in the table but they could not be determined exactly due to lack of uniform stand. In those areas where drain-



Cross sections of black spruce (left), Cedar (middle) and tamarack (right) trees of approximately equal age, one of each species (on left in each case) being stimulated by drainage, while the other stood too far back from the ditch to be affected by drainage

age is most effective on the upper side it is nearly always due to very slow natural movement of the water with the spoil bank on the lower side compacting the peat and partially cutting off the seepage from that side. The maximum distance back from the ditch to which drainage effect extends is given in the table, the averages being 252 feet for the upper side and 444 feet for the lower side.

Drainage for Increased Production. Most of the existing drainage ditches are one mile or further apart and from the foregoing figures it is evident that only a very small part of the land between the ditches is drained. The cost of constructing laterals and maintaining laterals and outlet ditches should thus be considered in determining whether the drainage of swamp forest land would be economic. It is believed that laterals 3 to 4 feet deep would be most economical as deeper laterals would usually require deepening of the outlet ditches. The cost of such laterals would probably be from \$1.00 to \$2.00 per rod. There is but little information available as to the proper spacing of laterals for swamp forest drainage and no doubt the spacing would vary greatly depending upon swamp conditions, but it is believed that where conditions are favorable for drainage, ditches $\frac{1}{4}$ mile apart would be satisfactory. Assuming a cost of \$1.50 per rod and a spacing of $\frac{1}{4}$ mile the cost of laterals would be \$3.00 per acre. Using for an example a stand which if drained could be cut in 20 years, and not including the cost of existing outlet ditches, the drainage cost would be as follows:

Initial cost of laterals	\$3.00 per acre
Simple interest on \$3.00 at 5% for 20 years	3.00
Maintenance cost of laterals	1.50
Maintenance cost of outlet ditches	1.00
Total	\$8.50
Overhead and contingencies (15% of \$8.50)	1.28

Total drainage cost over 20-year period \$9.78 per acre.

The cost of \$9.78 per acre is the drainage cost where there are existing outlet ditches and to this should be added any other cost such as taxes, cost of land and fire protection.

The average increased yield due to drainage was approximately one-third cord per acre per year as shown in the table. Using a current stumpage value of \$2.00 per cord, an increased yield of one-third cord per acre per year would amount to \$13.33 at the end of a 20-year period. Drainage would therefore be justified only when the drainage cost plus other costs was less than \$13.33, or if the value of the increased yield (\$13.33) be raised because of the convenient location of the stand or a general increase in price.

Another factor to be considered is the distribution of swamp timber. Very few stands were found which were large in extent. Usually one-half to three-fourths of the area between outlet ditches was either open swamp or

burned over timber. Due to this condition more feet of ditch per acre of timber would usually be required than if the stand was continuous.

CONCLUSIONS

1. Swamp trees showed increased growth following ditching in all cases where the water table was lowered. No trees were found to have been damaged by over drainage.

2. Sphagnum peat was least suitable for forest production in both the undrained and drained condition. Trees respond to drainage about equally well on sedge, woody sedge and woody peat.

3. Black spruce on sedge, woody sedge and woody peat showed about the same increase in growth following drainage as cedar. Tamarack showed less increase than black spruce or cedar but many of the trees were injured by the larch sawfly.

4. The drainage of swamp forest for timber production is economic only when one or more of the following conditions exist: (a) General increase in value of swamp timber; (b) value of stand above average due to its convenient location; (c) drainage cost held at a very low figure.

AUTHOR'S NOTE: The author gladly acknowledges his indebtedness to all of the cooperating agencies and members of their staffs for their aid and suggestions during the field investigations and especially to James L. Averell, junior forester, Lake States Forest Experiment Station, Forest Service, U. S. Department of Agriculture, who was co-author of a report of this work prepared for the cooperating agencies.

Intensive Farming on Expensive Land

DIVERSIFIED farming on land, some of which is valued around \$1000 an acre would appear at first thought to be a rather precarious undertaking, but W. B. Barr, Canton, Ohio, one of Ohio's Master Farmers of 1929, has shown that it can be done—with profit.

The partnership of Barr & Son practices a combination of dairying, poultry and fruit production, and general farming, on their 80-acre farm which lies just outside the city of Canton. The Barrs believe, in fact have proved, that they can readily carry on an intensive schedule of farming such as the foregoing by relying on labor-saving equipment, and utilizing all of their land for production of market or high grade feed crops.

One of the features of this place is the dairy barn which accommodates their herd of 60 cows. Complete modern equipment, running water, and facilities for handling feed and manure save time and labor. Manure is hauled regularly to the fields and helps to fertilize the potato and corn ground.

About 60 acres are utilized to produce potatoes, alfalfa, oats and corn. Field work is done with the tractor, and a team of horses help to do some of the light work. The average corn yield is 75 bushels per acre, and with a careful schedule of spraying, fertilizing, and cultivating the potatoes yield about 250 bushels to the acre.

Rehabilitation of Irrigation Districts¹

By W. W. McLaughlin²

THE subject of rehabilitation of irrigation districts is a broad one and will be treated in this paper in but a few of its aspects.

To rehabilitate, as used here, means to bring back into good repute and good standing those districts that are in financial difficulties; to provide for such districts an economic set-up that will make it possible for them to meet their obligations as they fall due; and ultimately permit the settler to become the owner in "fee simple" of his farm.

It must be understood, in the first place, that all districts do not require rehabilitation, since only relatively few of them are in financial difficulties. Usually the districts that do require rehabilitation are the newer ones, principally those undertaken at the time of the World War.

We are frequently asked "Why attempt the rehabilitation of irrigation districts at this time since there seems to be no immediate demand for irrigated farms? The primary object of rehabilitation work is not for the purpose of bringing into production additional acreage. Most districts have issued bonds, the proceeds of which were and are being used largely for the construction or acquisition of engineering works to be used by the district. These bonds have been sold broadcast, not only in this country but in many cases in foreign countries. The holders of the bonds have a just claim against the district, and having bought the bonds in good faith expect every reasonable means will be taken to pay the bonds in full. In some instances in the organization of a district there have been included existing farms, of which the holders went into the district in the same good faith as the purchaser of the bonds. New settlers have come into the district in practically all instances and invested their all, including frequently five or ten, or more, years of the best part of their lives. It is, therefore, a public duty to attempt to work out a salvation for these citizens.

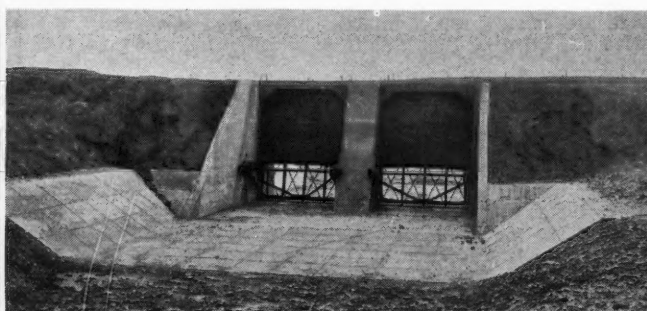
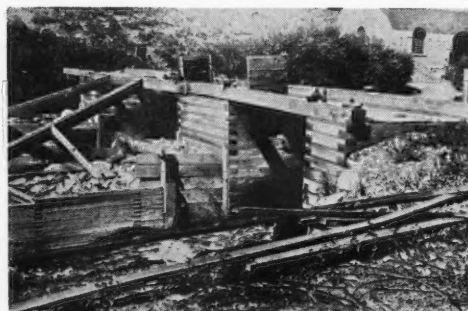
The irrigation district or any other political or semi-political division of the country that is in disrepute is an unhealthy locality from the standpoint of the state and of the nation. It should therefore be the policy of public agencies to clear up an unsatisfactory condition and make it healthy. In all instances the irrigation districts have been organized under state laws, and in many instances state officials have certified the bonds as just investments for public funds. There is in this latter instance more or

less of a moral obligation upon the part of the state to assist the individual purchaser of bonds and the settlers in finding a way out of their difficulties. Distressed irrigation districts, like any other unhealthy situation of a more or less public nature, detract from both the morale and the financial confidence of the people at large, and therefore demand public attention and help in maintaining public confidence.

The division of the federal government which I represent first became actively interested in the economic feasibility studies of irrigation enterprises through a request from the Secretary of the Interior to the Secretary of Agriculture to make such an investigation of a proposed federal project in Oregon. Immediately following this the State Certification Commission of Oregon requested this division, in cooperation with the Oregon Agricultural College, to advise as to the feasibility of a proposed irrigation district on which the state had been requested to certify the bond issue and advance the payment of interest for a period of five years. About the same time we were requested to make investigations of other districts in Oregon that were in financial difficulty, with a view of determining a means of rehabilitating such districts. We have also had similar requests from other states. During the past six or seven years we have devoted considerable time to the general subject of rehabilitation and feasibility of irrigation enterprises.

As a means of the agricultural development of the West up to the present time, the irrigation district has been an extremely important factor and will be of much greater importance in the future. Probably at the present time more than one-quarter of the area irrigated has been brought under irrigation by means of irrigation districts. The area irrigated at the present time under irrigation district organizations, exclusive of federal reclamation projects, is between three and four times the area irrigated within federal reclamation projects. These figures will give some idea of the importance of this form of organization to the development of irrigation in the West.

The total amount of outstanding bonds of irrigation districts in 1929 was \$185,000,000 as compared with \$105,000,000 in 1922. In Bulletin No. 1177 of the U.S.D.A. Division of Agricultural Engineering it is stated that 71 per cent of all irrigation district bonds sold to December 31, 1921, had been paid in full, both as to principal and interest. The percentage December 31, 1928, is just the same. Some of the bonds in default in 1921 have paid out in full, while some that were in good standing in 1921 have since defaulted. The same will be true of those in default and in good standing in 1928. As a business venture the buying of irrigation districts bonds has not



(Left) A dam in the American Fork River (Utah) where ditches for water for Pleasant Grove, American Fork, and Lehi are taken out. (Right) Outlet end of the Crane Creek sluiceway on the Lower Yellowstone project of the U. S. Reclamation Service near Savage, Montana.



(Left) Tappoons in an open ditch for cross furrow irrigation in a walnut orchard in California. (Above) Irrigation of young alfalfa for the first year by furrows between the borders

proven as hazardous during the past few years as the buying of stock in independent grocery stores, and not much more hazardous than buying stock in banks. We find in Trade Information Bulletin No. 627 of the U. S. Department of Commerce an estimate that in Louisville, Kentucky, more than 40 per cent of the independent grocery stores fail annually, and only a small part of those that fail come back again into existence although new stores spring up to offset the failures. This, however, does not alter the percentage of failures. In banking we find from figures compiled by the Federal Reserve Board that during the period 1921 to 1927 about 4500 banks, or about 15 per cent of the total in the country, failed; that the capital involved in these failures was about \$169,000,000 and the deposits about eight times that amount, or \$1,350,000,000. Also, as we know, the stockholders of the banks were liable for double the amount of their investment. If we took up a review of the railroads and their development in the United States, we would probably find that irrigation district bonds were comparatively safe, if we based our conclusions on past performances of the railroad and irrigation district development.

Irrigation district bonds have suffered a depression in the market, until at the present time there is very little sale for such securities. The depression in bond prices is not confined to irrigation district issues. In fact, irrigation district bonds are not the only ones that are hard to sell on the market. During the present month the city of San Francisco, after many months of effort, has just succeeded in disposing of \$41,000,000 of municipal bonds of unquestioned standing. There seems to be no rhyme or reason to the irrigation district bond market. Edward Hyatt, state engineer of California, in a paper recently delivered at a convention of western state engineers at Reno, brings out the fact that bonds of one California district, which under a long term power contract with a responsible concern provides for the payment of 80 per cent of its bond interest through sales of water for power, are quoted on the market at 40. In another district in the state, where only one-third of the district is developed and all of the water has been used in this development, the bonds are quoted at 90, and there is no power possibility.

Several attempts have been made by various states to stabilize the price of irrigation district bonds. The state of Washington provided through taxation a fund for the purchase of such bonds, but stopped the levy when about \$3,500,000 had been accumulated. Oregon in 1919 amended its constitution to permit the interest on irrigation district bonds to be advanced by the state for a period not exceeding five years. Repeal of this amendment is to be voted on at the next general election. Wyoming has

brought irrigation district bonds and to date all such bonds purchased are in good standing. California has never followed a policy of aiding development by purchase of irrigation district bonds, but in a number of instances has invested state funds in bonds of selected districts. Utah attempted irrigation development by constructing irrigation works, but with little success. California has devoted its efforts primarily to land settlement programs on two districts initially financed by the state. Ten of the states have at one time or another provided for the certification of irrigation district bonds by state commissions. In three states these acts have been repealed.

Before we can prescribe for irrigation district failures, we must first diagnose the case. Irrigation district failures may be attributed to four general causes: (1) Engineering mistakes, (2) exploitation, (3) colonization difficulties, and (4) changes in the financial and economic situation. As a result of our studies we found that the principal causes of failure without regard to importance, may be listed more specifically as follows:

1. **Aftermath of the War.** Many of these districts were started immediately following the War when prices and construction costs were high.
2. **Lack of Settlers on the Projects.** Probably one of the greatest causes of failure.
3. **The Spreading of Cost,** that is, including within the boundaries of the district land that is not capable of paying its share of the cost. Many of the promoters work on the policy that the greater the area, with the construction cost of the work remaining the same, the less the per acre cost. Yet, if the land is not capable of producing sufficiently to meet this cost, it is a liability rather than an asset.
4. **Lack of Sufficient Water.** In one case coming under my personal observation the water supply was sufficient for only approximately one-half of the area included in the district, and yet every acre in the district was assessed the same.
5. **Improper Financing.** By this is meant terms of repayment beyond the ability of the land to meet. In some instances bonds matured in ten or twenty years, and yet the proceeds from the land could not meet the bonds and interest unless spread over a term of forty to fifty or even sixty years.
6. **Uniform Assessments for Bond and Interest Payments.** That is, every acre of land within the district that was irrigable was assessed upon a uniform basis irrespective of the ability of these lands to produce, or of ad valorem valuation. If the amount to be collected from these lands was on a basis of the return from the poorer lands then the district could pay out. If, however, as was

invariably the case, the basis of payment was on the productivity of the average land, or, as it is termed, the average productivity, then those acres below the average could not meet their payments and defaulted because the acres above the average would not share their surplus to make up the deficiency of the poorer acres.

7. The Development of Alkali and Water-Logged Areas. In most of the irrigated sections of the world, the lands are prone to become alkaline or water-logged, or both, unless adequate natural or artificial drainage exists. Most frequently in the younger districts there existed no means of legal credit for providing artificial drainage when alkaline or wet areas developed, and land so affected was soon unable to meet the payments.

8. Litigation. Frequently litigation over water rights occurred and retarded development as well as proving a financial burden which the district could not meet.

9. Lack of Capital by Settlers. Since many of the settlers coming to new projects were lacking in capital, and further since they did not have sufficient collateral for loans to develop their lands, they were not able to make such developments with sufficient rapidity to meet their payments. Credit when it was at all available was at an excessively high rate of interest. In fact, one of the greatest stumbling blocks to the development of new areas where immediate payments must be made for the purchase of land or water, or both, is suitable credit for the settler during the development period.

10. Lack of Proper Economic Consideration to the Project. This is also one of the greatest causes of failure. One district that came under our observation, while a small district of only 8,000 acres, had its financial set-up based upon truck crops. This was an economic mistake for several reasons, principally because there was not a supporting market, and to transport the material to distant markets was prohibitive. In another district of very large area the basis of financing was presupposing the entire area in fruit and attempting to make fruit growers out of all the settlers. This district was also set up on a basis of 4 per cent interest on bonds, and of course practically none of the bonds were sold.

11. Faulty State Laws. This is not so serious, except in probably one particular, and that is because there is no adequate means provided for settling the affairs of the district that is in financial difficulty.

12. Land Areas Within a District in too Large a Single Holding. A single farm unit that is too large to be operated by the owner soon becomes a difficulty, unless the owner can meet his payments from outside sources.

13. Unsound Engineering. For instance, in one district the irrigation period extended over 150 days. The canal and distributing system was designed for a uniform quantity of water throughout the 150 days that would deliver to the land in that period of time the equivalent of 3 acre-feet of water per acre. No account was taken of the fact that probably 60 per cent of the water was required in six weeks to two months time. This system was therefore inadequate to meet the demands of the district, and neither money nor credit was available to correct this defect.

14. Psychological Features. The principal one among these is the practice in some sections of allowing deferred credit to old settlers for water rights. That is, a settler within an area that is to be organized into a district embracing much additional land is allowed a credit for the water rights he has depending upon the sufficiency of his water right to meet his needs. If he has 85 per cent of sufficient water to irrigate all of his land he could be entitled to a credit of 85 cents on the dollar for all future assessments. Frequently such land is the better land of the district and is a going farm unit that can meet its payments promptly. When the less fortunate neighbor, with new and undeveloped land has to put down a dollar to the old settler's 15 cents, it has a depressing and deterrent effect upon the new settler.

A Few of the Remedies Proposed. As a result of our experience the following remedies are suggested for some of the causes leading up to district difficulties:

1. A careful economic and feasibility study by competent disinterested persons.

2. A careful supervision by a public agency of the district expenditures during construction.

3. A well-defined and properly financed settlement program.

4. Individual liability with a small general liability. At the present time nearly all irrigation district bonds are on the basis of what is known as blanket liability. In other words, all of the lands within the district are held as security until all of the bonds and interest are paid. Under individual liability, with a small additional general liability to care for contingencies, the settler can almost entirely relieve himself of his neighbors' liability, with therefore a great incentive to meet his own payments. Upon the other hand, in case of financial difficulty under general liability, the incentive is for the settler not to pay, because the pyramiding of delinquencies will soon put him out of business. Under individual liability the bond is in effect a general liability to this extent: it does not cover any specific piece of land and all payments made by individuals are prorated among the bondholders, but when a settler has met all his assessments plus the small penalty, his land is no longer subject to the bonded debt.

5. Ad valorem and benefit basis of assessment. In other words, it is the return from the land that must pay the bonds and the interest. The basis of assessment should be therefore the ability of these lands to produce, with due credit being given for location.

6. Terms of repayment of bonds and rates of interest that can be met from the proceeds of the land.

7. There should be provided in the state laws a means of foreclosing on irrigation districts, and for the district to go into receivership, either voluntarily or by court order.

8. Provision should be made for the collection of operation and maintenance charges separately from the collection of general taxes and taxes for bond and interest payments, because if the district can not operate it soon deteriorates and the settlers soon move away.

The question naturally arises as to what is involved in revamping or rehabilitating an irrigation district:

1. The bond of a district is a contract between two parties and can be broken legally only by and with the consent of the two parties to the agreement.

2. It is therefore necessary to provide a bondholders committee and a landholders committee that negotiations may be successfully undertaken.

3. There is involved the consideration of agriculture, engineering and economic problems in addition to the human element.

4. In many cases it takes amendments to state laws and therefore requires an intervening legislative session before such readjustment can be put into effect.

5. A ratification of the findings of the committees, in the case of the landowner by a popular vote, and in the case of the bondholder by written consent.

6. Usually a loss upon the part of both the bondholder and the settler.

The revamping and reorganization of an irrigation district that is in difficulty requires a diversity of highly specialized technical training and experience as well as a world of patience and ability to deal with the public. Each district is different in its problems, and there is therefore a fascination about such studies and a great satisfaction when the affairs of the district have been satisfactorily adjusted, and one can see the settlers once again prospering and meeting in full the terms of their obligations.

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Requests for copies of publications abstracted should be addressed direct to the publisher.

The Insulation of Fruit and Vegetable Storages, R. D. Anthony and F. G. Hechler (Pennsylvania Station (State College) Bulletin 241 (1929), pp. 28, figs. 11).—This publication presents the results of cooperative research on the subject by the station and the Engineering Experiment Station of Pennsylvania State College.

The results indicate that large air spaces in walls are not efficient. Air spaces should be closed at the bottom and at the top. The tests indicate that the best width is from 0.75 to 1 inch. Such a space has about the same resistance to heat transmission as 5 inches of brick wall or 10 inches of concrete, but has only one-third to one-fourth as much as the same space filled with a good insulating material. Since a 0.75-inch air space seems to be the most suitable from the standpoint of insulation and construction, the most efficient arrangement for insulations of the blanket or semirigid type is to place them between the studs, with an air space on each side, rather than in contact with the sheathing on one or both sides. It was found that when blanket and board forms of insulation are built into solid floors or ceilings they are not as efficient as when they are used in layers with air spaces between. Light colors on the roof and walls of a building reflect more heat and absorb less than the darker colors. Windows should be omitted from the storage unless they are absolutely necessary.

The conclusion is also drawn that concrete floors should not be used in air cooled storages because they make the air so dry that the fruit and vegetables will shrivel. A dirt is considered better. It has been found that a well-kept grass plat with shrubs and shade trees is of definite value in modifying temperature changes in a fruit storage. Such a storage will be cooler in summer and warmer in winter than a similar structure in a bare and exposed location.

Data from observations of different vegetable storages are presented. An analysis of these indicates that if the exposed walls of a bank cellar approach one-half the total wall surface, additional heat is necessary to prevent freezing in the storage unless these exposed walls have greater resistance to heat flow than is furnished by field stone or concrete. It appears that the ceiling presents a larger surface for heat loss than the walls. In the above-ground storage set directly upon the ground, the earth influence is sufficient to give adequate protection and maintain temperatures as high as 38 degrees (Fahrenheit) provided the walls and ceiling are properly insulated. In south-eastern Pennsylvania 4 inches of regranulated cork with the necessary wood and paper sheathings or its equivalent are sufficient. In the cooler areas of the state 6 inches of cork or its equivalent should be used. Air leakage around doors was found to be a large factor in lowering temperatures to a dangerous degree in severe weather, especially in the above-ground storage.

It is concluded in general that frostproof farm storages may be easily and economically constructed when proper use is made of the heat which is given off by the ground during the winter. These storages should have temperatures that run between the ground temperatures and those of the outside air the greater the contact with the ground and the less the heat by ventilation or leakage through the walls the closer the storage temperature approaches that of the ground.

Feed-Lot and Ranch Equipment for Beef Cattle, W. H. Black and V. V. Parr (U. S. Department of Agriculture, Farmers' Bulletin 1584 (1929), pp. II + 22, figs. 30).—Practical equipment which is more or less essential in the successful handling of beef cattle on the range and in the feed lot is discussed in this bulletin and illustrated by drawings and photographs. This includes sheds, windbreaks, self-feeders, feed troughs, hayracks, watering tanks and troughs, feeding floors, silos, scales and scale pens, dehorning and branding chutes, corrals, dipping vats and cattle guards.

Electric Power for the Farm, E. W. Lehmann and F. C. Kingsley (Illinois Station Urbana, Bulletin 332 (1929), pp. 373-479, figs. 30).—The results of a study of the use of electric power on Illinois farms are presented in considerable detail, and it is pointed out that the distribution of electric power in the state has reached a point where many areas remote from the centers of population have electric service available. This study differed from similar projects in which individual items of equipment were studied in that a number of pieces of equipment were installed on each farm, and the use, value, and energy requirement were determined in relation to other types of equipment. It was found that the cost of wiring and

fixtures and the cost of electrically operated equipment incident to the use of electric service are the two factors which limit its use on the farm. The farms on the experimental line use more electricity in the home than in production work, the kitchen range and the household refrigerator consuming the most electricity. The results of tests demonstrated that electricity is an economical and practical form of energy for operating milking machines, cream separators, seed germinators, feed grinders, silage cutters incubators, brooders, pumps, portable motors, wood saws, feed mills, and other power-driven equipment. The ten cooperating farmers on the experimental line were found to be using about five times as much electric energy as the average city lighting customer. The results in general indicate that many farmers can make sufficient economical use of electric energy to justify power companies in building farm lines. The unit electric plant was found to furnish sufficient energy for lighting and for operating small motors and small appliances. However, the cost of energy from the unit plant is greater than from the central station plant when served under existing rates in effect on the experimental line.

Methods of Research in Soil Dynamics as Applied to Implementation Design, M. L. Nichols (Alabama Station (Auburn) Bulletin 229 (1929), pp. 27, figs. 17).—The object of the study of the soil properties discussed in this publication is to obtain a basis for the design of tillage implements. For the purpose of determining the properties affecting design, a small nickel-plated plow was mounted to run beside a glass surface permitting observation of the reaction within the soil. From this and supplemental studies a chart of the variables entering into these reactions was prepared. The study then resolved itself into a determination of the interrelationship of the factors through their most probable range of variation. New methods were evolved for moistening soil and measuring resistance to compression, arch action, cohesion, shear, friction, adhesion and the effect of shape of surface applying pressure to the soil. Data are reported showing the application of the methods. The study of friction between metal and soil was carried far enough to formulate definite laws covering this phase.

Farm Lighting, F. C. Fenton and O. D. Hunt (Kansas Agricultural College (Manhattan) Extension Bulletin 64 (1929), pp. 17 figs. 15).—Practical information on the subject is given, special attention being devoted to the use of electricity for the lighting of dwellings and animal shelters.

Tests of Strength and Design of Welded Joints (Heating, Piping and Air Conditioning, 1 (1929), No. 5, pp. 384-387, figs. 8).—The results of an investigation of oxyacetylene welded pipe joints are reported.

These indicate that a properly made oxyacetylene welded joint is as strong as the pipe—fully 100 per cent efficient. The single V-type butt joint is the most efficient and is recommended for use in welding pipe. This is in agreement with past experience as this design is practically universally used in pipe work.

Very high strength and nearly equally satisfactory results were obtained with the normal socket and socket with groove joints. In joint design, however, other factors must be considered, as cost of preparation, stress distribution under strain, and ease of welding, which make these designs less satisfactory than the single V-type butt joint. The weakest joint was the socket with welded rivets. This design should not be used because of cost, difficulties in welding, as well as lower joint strength.

Due regard must be given to penetration and to the shape of the joint, particularly the reinforcement of the weld. This is more important in the larger than in the smaller pipe sizes. Butt welds should be reinforced at least 25 per cent and should be built up so as to present a gradual increase in the reinforcement from the pipe wall to the center of the weld. Fillet welds, when used, should be built up well in excess of the wall thickness of the bell.

There is no detrimental heat effect or structural weakening of the pipe metal due to welding.

The uniformly high strength obtained in these numerous joint tests points out the dependability of properly made welds. With qualified welders under proper control methods, a pipe joint of maximum efficiency can be consistently and uniformly made by the oxyacetylene process.

Land Drainage and Reclamation. Q. C. Ayres and D. Scoates (New York and London: McGraw-Hill Book Co., 1928, pp. VIII+419, figs. 283).—This book deals with the drainage, reclamation, and surveying problems that arise on the average farm, many of which the farmer himself can handle. It is based largely on experience at the Iowa State College and the Texas Agricultural and Mechanical College and at a number of other Land Grant and Federal institutions.

An effort is made at the outset to acquaint the reader with the broad aspects of land reclamation, and in the chapters on surveying the use of the level and tape is treated at some length. The compass and its use in land surveying are also discussed in detail.

In the surface-drainage portion of the text considerable attention is devoted to the drainage district, this chapter being a contribution from the U. S. D. A. Office of Experiment Stations. Considerable space is also devoted to terracing, land clearing, and legal principles relating to farm waters.

Other chapters are included on drainage properties of soils, rainfall and run-off, open-ditch design, open-ditch location and construction, open-ditch maintenance, earth dams and levees, explosives and their use, subsurface drainage, location of tile drains, design of tile drains, selection of tile, installation of tile, drain tile accessories, estimating cost of tile drainage, special methods of drainage, and practical tile-drainage problems.

Investigation of Warm-Air Furnaces and Heating Systems. IV, A. C. Willard, A. P. Kratz, and V. S. Day (Illinois University, Engineering Experiment Station (Urbana), Bulletin 189 (1929), pp. 116, figs. 49).—This is the sixth of a series of reports of studies on warm-air furnaces. It deals entirely with the work accomplished in a specially designed research residence.

A comparison of the performance of a furnace in the laboratory with that of the same furnace in the research residence showed that the plant in the residence operated at lower capacity, efficiency, and register air temperature than did the laboratory plant. Less heat was given up to the recirculating air in the residence than in the laboratory plant. The temperature of the flue gases leaving the furnace in the former plant was also found to have been 85 degrees (Fahrenheit), or approximately 15 per cent higher than in the latter, at a 6-pound combustion rate. The deficiency of the plant in the research residence resulted in a reduction in temperature of the air emerging from the registers and a reduction in the quantity of air flowing. The combined effect amounted to a 20 per cent reduction in capacity. The reduction in temperature amounted to approximately 6 degrees at the register, at a combustion rate of 6 pounds.

The data also showed that at any given rate of combustion in the furnace the air will be delivered at three floor levels at three different temperatures. It appears, therefore, that a system may not be designed to operate at the same temperature at all three floors.

Tests of the general performance of the residence heating plant showed that with soft coal in zero weather there was a flue loss at the furnace of 39 per cent of the heat of the fuel. About 26 per cent was finally lost from the top of the chimney. With hard coal the flue gas losses in zero weather at the furnace represented only 21 per cent of the heat of the fuel, and only 8 per cent was finally lost from the top of the chimney. When hard coal was fired the overall efficiency ranged from 92 to 97 per cent, averaging 95 per cent for average weather. With soft coal the overall efficiency averaged 75 per cent.

It was also found that exactly three-fourths of the heat available at the bonnet was delivered at the registers. This loss of 25 per cent between furnace and registers has the effect of reducing the efficiency of the system as a whole. With either hard or soft coal the indirect heat exceeded in amount the heat delivered at the registers.

A comparison of six cold air recirculating systems showed that in general, somewhat better room temperature conditions may be obtained by returning the air from positions near the cold walls. Friction and turbulence in elaborate return duct systems retard the flow of air and may seriously reduce furnace efficiency and lessen the advantages of such a design. The cross-sectional duct area is not the only measure of effectiveness. Friction and turbulence may operate to make the air flow out of all proportion to the duct areas.

A study of the effect of sunshine and wind on heating conditions showed that in coldest weather sunshine on the roof resulted in a 30-degree increase in the temperature of the roof, and an 8-degree increase in temperature of the gable spaces. In mild weather (20 degrees indoor-outdoor difference) sunshine increased the roof temperature over 50 degrees and increased the gable-space temperature about 12 degrees. Only in extremely cold weather was the flow of heat outward through the roof when the sun was shining, and for weather warmer than 17.5 degrees (indoor-outdoor difference 52.5 degrees) the flow of heat was inward through the roof when the sun was shining. The flow of heat during periods of no sunshine was outward, the gable spaces being at higher temperature than the roof surfaces. In very cold weather this loss of heat was accentuated by a wide difference between the two temperatures.

A comparison of temperatures in the attic spaces in which an insulating blanket was laid over the joists with those recorded when no blanket was used showed that in coldest weather the use of the insulating material resulted in a reduction of 5 or 6 degrees in the attic temperature. This reduction indicates that the heat transmission through the ceiling and insulating blanket was less than through the ceiling alone. It also indicates that the temperature difference through the insulated ceiling was greater than through the uninsulated one, a condition which must be taken into account in estimating the value of insulation materials.

A test of fuel consumption and economy with six varieties of solid fuel showed that Pocahontas coal possessed the greatest number of economical characteristics, such as least tonnage, least ash handling, and least cost. Soft coal, having the lowest unit price, was not the cheapest coal for the season, and required the greatest tonnage. This fuel, though unsatisfactory, from the standpoint of smoke, soot, ashes, and low thermal efficiency, has the advantage of quick ignition with rapid acceleration of the fire. No one chemical or physical characteristic of the fuels alone controls the consumption. The results also showed that tonnage varies directly as the product of ash and volatile matter divided by the heat value.

The results of a large number of other tests of a detail nature are also reported.

Book Review

"Report of the American ICOR Commission" is interesting and informative reading on the Jewish agricultural colonization made necessary and possible by the Russian revolution. Icor is an American organization promoting principally the colonization of Biro-Bidjan in the Soviet Far East, north of Manchuria and Mongolia. To determine in detail the possibilities of the area and the manner in which it could best promote the colonization, Icor sent a commission of specialists in the spring and summer of 1929, to investigate. A.S.A.E. members on the commission were J. Brownlee Davidson, head of the department of agricultural engineering at Iowa State College; Benjamin Brown, farmer and cooperative marketing specialist; and Charles Kuntz, sociologist and agriculturist. Substance of their report: History of the movement, geography and geology of the area, climate, natural resources, agriculture and industry, commerce, recommendations of the commission, etc. Outlook: There are numerous difficulties to be faced but none that are insurmountable. Biro-Bidjan and the Russian Far East are "a vast empire in the making." Publisher: Icor, 799 Broadway, New York, N. Y. Price, 50 cents.

"Economic Survey of Certain Federal and Private Irrigation Projects, 1929" is printed as a report of the Bureau of Reclamation, U. S. Department of the Interior. The late George C. Kreutzer, director of reclamation economics, was chairman of the committee which made the report. Most of the committee members are not employees of the Bureau of Reclamation but undertook the work as a public service. Their survey shows the conditions found on the 21 projects surveyed, the cause of the conditions and changes in reclamation law and policy which are needed. Two of their conclusions of particular interest and importance are:

- (1) There should be greater participation on the part of the states in the financial and other responsibilities of construction, settlement, operation and maintenance of the Federal projects.
- (2) A source of credit should be provided to take care of the needs of settlers in the early years of changing raw lands into a producing farm.

The Bureau of Reclamation will be glad to furnish copies of this bulletin to interested parties.

"Comparative Strength Properties of Woods Grown in the United States," by L. J. Markward of the Forest Products Laboratory, U. S. Forest Service (Technical Bulletin 158) presents in popular form information on the strength, weight and shrinkage of 164 native species of wood, based on over a quarter of a million tests. The information is arranged on a comparative basis to facilitate selection of species for different uses. The bulletin should be of value to manufacturers, lumber dealers, lumbermen, engineers, architects, and others interested in the comparative strength of species from the standpoint of manufacture, merchandising, and use. This publication, now in the course of preparation, will be sent free to those requesting it as long as the supply lasts. If you wish to obtain a copy, send your request promptly to the U. S. Forest Products Laboratory, Madison, Wisconsin.

"Properties of Haynes Stellite," is an engineering pamphlet giving detailed data on the stellite alloys, their red hardness, physical properties, chemical properties and structure. The uses are also briefly mentioned. Haynes stellite is a patent alloy metal with unusual hardness properties which has been on the market for some time. It has been used mostly in making metal cutting tools and, in agriculture, to prolong the sharpness of plow shares.

Who's Who in Agricultural Engineering



L. E. Hazen



F. A. Lyman



W. L. Paul



O. B. Stichter

L. E. Hazen

Leslie Eugene Hazen (Mem. A.S.A.E.) is professor and head of the department of agricultural engineering at Oklahoma Agricultural and Mechanical College. He received his bachelor's degree in agriculture at Kansas State Agricultural College in 1906 and was graduated as a mechanical engineer from Sibley College, Cornell University, in 1916. Made assistant professor of farm mechanics at the New York State College of Agriculture and superintendent of tractors for the New York Food Commission, he held these positions until he went to New Jersey in 1918 to be professor and head of the department of rural engineering at Rutgers University. In 1919 he accepted his present position. In Oklahoma he has taken a particularly active part in promoting erosion control, rural electrification, and the improvement of farm buildings. Since being elected to membership in the Society in 1919 he has been active in the structures and land reclamation phases of its work, and in the Southwest Section. Among his many writings his most recent contribution to AGRICULTURAL ENGINEERING is "Building Design for Southern Conditions," a paper presented at a joint meeting of the Southern and Southwest Sections of the Society and published in the June 1929 issue.

F. A. Lyman

Frederic Addison Lyman (Assoc. Mem. A.S.A.E.) is managing director of Farm Fence Institute. Born and raised on an Iowa farm, he operated the home farm for a year after graduating from high school; became convinced of the desirability of learning more about labor-saving machinery; went to Iowa State College to study about it. In four intensive years there he earned his bachelor's degree in agricultural engineering; studied technical journalism as a minor subject and was outstanding as a student journalist; was a leader in extra-curricular activities and elected to various honorary organizations. Before graduating he spent a summer in the experimental department of the John Deere Plow Works. Since receiving his degree he has combined his ability along journalistic and engineering lines in advertising and publicity work, first in the research department of the National Association of Farm Equipment Manufacturers and since May, 1929, as managing director of Farm Fence Institute. In that capacity he has charge of market analysis, economic research and publicity concerning the value and use of farm fences. His affiliation with the Society dates back to his undergraduate days when he was a student member.

W. L. Paul

W. L. Paul (Mem. A.S.A.E.), chairman of the Pacific Coast Section of the American Society of Agricultural Engineers, is machine designer for the John Deere Plow Company, San Francisco, California. After three years of engineering study at the University of Illinois he obtained a position as draftsman with Nicol, Burr and Company. After about a year he went to the Kingman Plow Company as draftsman; in another year he went to the Moline Plow Company for a five-year stay in drafting, advertising and accounting work; spent six years with the Bradley Manufacturing Company as draftsman, designer and assistant superintendent; was employed by the Oliver Chilled Plow Works as chief designer; and in 1912 after six years in that position, left the Middle West for the Pacific Coast. In San Francisco he was with the John Deere Plow Works for three years, switched back to the Oliver organization in its San Francisco branch for two years; then in 1917 returned to the John Deere fold. While in California he has specialized in developing tillage tools to meet the needs of that state. Hitches are a hobby of his. In the early days of the tractor he established a world record by hitching 55 14-inch bottoms in one unit pulled by three tractors, turning 64 feet of furrow, and plowing at the rate of one acre in four minutes. He has also invented and patented many mechanical devices. He became a member of the Society in 1926, was elected vice-chairman of the Pacific Coast Section for 1929 and was recently elected chairman of the Section for 1930.

O. B. Stichter

Otto Bismark Stichter, (Aff. Mem. A.S.A.E.) is manager of the eastern branch of the Loudon Machinery Company, at Albany, N. Y., in charge of the sale and distribution of his company's equipment on the eastern seaboard. A native of Iowa, he is a son-in-law of William Loudon, one of the founders of the company. He served in the Spanish-American War as a sergeant in the 50th Iowa Volunteer Infantry. Although not a professionally trained engineer the 31 years he has spent in the manufacturing, sales and executive work of this company have made him thoroughly versed in the application of engineering to agriculture so far as the products of the company are concerned. Affiliating with the Society in 1925, he has been active in the North Atlantic Section and a consistent worker in building up its membership. He is serving his third consecutive term as secretary-treasurer of the Section

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Contributions of interest and value, especially on new developments in the field of agricultural engineering, are invited for publication in this journal. Its columns are open for discussions on all phases of agricultural engineering. Communications on subjects of timely interest to agricultural engineers, or comments on the contents of this journal or the activities of the Society, are also welcome.

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RAYMOND OLNEY, Editor
R. A. Palmer, Assistant Editor

A Principle in Reclamation

SINCE the war-inflated agricultural balloon crashed to earth in 1921 numerous self-appointed committees have investigated; sought to fix the blame. Many accusing fingers have pointed toward land reclamation activities and the men behind them. Under the shadow of suspicion some of the former advocates deserted the cause, some became passive, others stood ready to defend it at any cost.

Gathered together in Kansas City, Missouri, during the last days of December, 1929, the staunch reclamationists in the American Society of Agricultural Engineers laid down an unquestionable principle. Lands should be made to net continuously the greatest possible benefits to both the owner and the general public. That is only sound and economic conservation of natural resources.

In numerous papers they presented facts and figures which vindicate, under that principle, current reclamation projects and expenditures. Many of these papers are published in this issue for the information of all agricultural engineers and others who may be interested.

The Land Reclamation Division of the American Society of Agricultural Engineers has taken a position which the Society as a whole can and should support. The Kansas City meeting and the principle laid down there may well become the turning point of the whole public attitude toward reclamation.

New Demands

C. F. KETTERING says, in substance, that most engineering graduates are earning small salaries because engineering education has not taught them enough economics and psychology.

The smoke of such accusations hangs heavy about engineering curricula. Where there is so much smoke there must be some fire. One of the burning questions is: How broad a field should engineering cover? Certainly it should continue to include the forces and materials of nature with which it has traditionally dealt. Should engineers not also master any other forces or materials which become important considerations in the progress of their work?

Economics and psychology have become important con-

siderations in the progress of engineering work. Marketability, manufacturing economy and labor relations are of as much concern to engineers today as strength of materials, perfection of design, or efficient use of power.

But economics and psychology cannot simply be added to the subject matter requirements of the undergraduate engineer. Engineering is already known as a "stiff" course. Possibilities for adding these sciences are three.

Increased teaching efficiency is probably the least of these. If teachers could put across their subject matter more efficiently, more ground could be covered by the student. We say this is least important only because we believe engineering teachers are making progress in this direction about as rapidly as can be expected.

Prolongation of the period of preparation is a solution of the problem for students who have the means, inclination and ability to spend five, six or more years in school. It can be applied individually by such students to meet such training needs as each may foresee for himself. Sufficient calling of attention to the importance of economics and psychology should stimulate this group to get a foundation in these subjects sufficient to serve as a basis for future independent study.

The possibility of curriculum rebuilding is complicated by the two opposite schools of thought, the one of which believes in turning out square pegs to fit square holes and round pegs to fit round holes; and the other which holds to turning out semi-finished octagonal pegs which can be trimmed to fit either type of hole. Each has its advantages and disadvantages which are aside from the point. What is significant is that economics and psychology can be argued as applicable to either type of curriculum. They might be used to turn out new varieties of engineering specialists which some industries are apparently demanding, or they could equally well be used to further broaden the foundation and increase the adaptability of the products of engineering colleges which turn out engineers as such.

An Employer's Reaction

WE LEAVE to your imagination the weakness and futility of the application for a position which brought down the following condemnation from an executive in a large farm implement manufacturing company:

"The other day we received an application from an agricultural engineering graduate. It was one of many that we receive, all of the same general ineffectiveness, with hardly any information except the name and address, and the fact that he would like a job.

"The situation, as we look at it, is serious. Certainly a group of men who have spent four years in college and are ready to graduate should know more about how to go after a job. Not only are they careless in their writing, but they are careless in the selection of paper, they give no information, and do not show the slightest intelligence as far as the necessary steps to seeking a position are concerned.

"We have had many excellent trainees. Most of them have gone out and made good, but it has been a hard fight with many of them to overcome their inferiority complex. While we do not want men who are too forward or assertive in connection with their knowledge, ability, desires, etc., yet we do feel as if much can be done to improve agricultural engineering graduates."

Here is concrete evidence that agricultural engineers need to know something about economics and psychology. Anyone having a working knowledge of these subjects would use at least as much care in making his application for a position as an employer would demand of him in his work; would show what he could do for the prospective employer; and would show in his application the same attitude of mind, the same personality which the work would require.

A. S. A. E. and Related Activities

Progress of Annual Meeting Plans

SPLENDID progress is being made in developing the plans for the 24th annual meeting of the American Society of Agricultural Engineers at Moline, Illinois, June, 16, 17, 18 and 19, 1930.

Acceptances have been secured from practically all the speakers invited to contribute to the program of the general sessions.

Monday forenoon, June 16, will be devoted to a session of the College Division, and the evening of that day will be given over to an extension agricultural engineers session.

The afternoons of all four days will be given over to factory inspection trips in the Quad-Cities—Moline, Davenport, Rock Island, and East Moline—and field demonstrations of agricultural machinery.

The forenoons of June 17, 18 and 19 will be devoted to general sessions, at which will be featured subjects of timely and important interest to agricultural engineers. The speakers for these sessions are nationally known and will have messages of vast significance.

Professional divisions will not present technical programs, but simultaneous business sessions of each division will be held on the evening of Tuesday, June 17, following the annual business meeting of the Society.

The annual dinner of the Society will be held the evening of Wednesday, June 18.

Southern Meeting Reflects Increased Interest in Agricultural Engineering

A JOINT meeting of the Southern and Southwest Sections of the American Society of Agricultural Engineers in conjunction with the annual meeting of the Southern Agricultural Workers Association in Jackson, Mississippi, February 5, 6 and 7, is reported as indicating increased interest and activity in agricultural engineering in the states represented. Sessions were well attended and unusual interest was shown in the subjects presented.

The program, which followed substantially the tentative program published in AGRICULTURAL ENGINEERING for January, gave attention to cotton as the leading crop of the area, and to power farming, irrigation, terracing and rural electrification. Phases of research taken up, in addition to that applying to cotton, pertained to farm structures and soil dynamics.

A business meeting was held by the Southern Section at which officers for the ensuing year were elected. J. W. Carpenter, Jr., assistant professor of agricultural engineering at Mississippi A. & M. College, was elected to the chairmanship; E. C. Easter, agricultural engineer for the Alabama Power Company and J. H. Craig, International Harvester Company, were made first and second vice-chairman, respectively, and A. Carnes, assistant professor of agricultural engineering at Alabama Polytechnic Institute, was selected as secretary.

It was also pointed out at this meeting that by devoting a special issue of AGRICULTURAL ENGINEERING to the South and its agricultural engineering problems and progress, the American Society of Agricultural Engineers could stimulate and help to unify the interest along these lines which is developing in that part of the country. It was decided that the secretary of the Section should investigate the possibilities of the proposition.

Agricultural Engineers Take Part in Drainage, Conservation and Flood Control Program

FIVE agricultural engineers presented papers before the 19th annual session of the National Drainage, Conservation, and Flood Control Congress in St. Louis,

Missouri, February 20 to 22. These agricultural engineers, their positions, and the titles of their papers are: W. H. McPheeters, agricultural engineer, Portland Cement Association, "Soil Conservation, an Aid to Flood Control"; A. J. McAdams, engineer, agricultural extension section, E. I. du Pont de Nemours and Company, "The Use of Explosives in Maintenance of Open Drainage Systems"; Lewis A. Jones, senior drainage engineer, Bureau of Public Roads, U.S.D.A., "The Effect of Vegetative Growth on the Capacity of Drainage Channels"; C. H. Young, consulting engineer, Central States Engineering Company, "Correlation of Farm, District, and State Drainage Work"; and D. Howard Doane, Doane Agricultural Service, "Making Drained Land Pay."

Agricultural Engineers in Honorary Fraternities

MORE than 92 per cent of the agricultural engineering personnel of the land grant colleges are members of one or more honorary fraternities, according to figures given by L. J. Smith, head of the agricultural engineering department, at the State College of Washington, who has recently made a study of this subject. These figures show that these agricultural engineers have a good undergraduate scholarship record and that they have shown a wide interest in activities outside of their immediate college training.

American Engineering Council

SEVERAL bills which Council has supported have recently been passed by Congress. Most important to engineers is the one which provides for completing the topographic survey in eighteen years instead of the eighty to one hundred years which would be required at the present rate of work. This means that the appropriation for this work next year will be about \$1,000,000; several times greater than the appropriation for any previous year. It is to be increased yearly to a maximum which will permit completion within the eighteen years. The increased rate at which the work will be carried on will rapidly make available maps needed in irrigation, flood control, hydroelectric developments, improved highways, improvement of rivers for navigation, city planning and other engineering projects. Incidentally it will require the employment of a greatly increased number of engineers to do the mapping.

Other governmental agencies which have recently felt the increased emphasis of the present administration on engineering and scientific research are the Forest Service, granted a three and a quarter million dollar increase in its appropriation, and the water resources division of the U. S. Geological Survey, which is to receive more than five hundred thousand dollars per year, an increase of more than one hundred per cent. This will enable the division to cooperate with individual states in this work on a fifty-fifty basis.

Bills for the establishing of a national hydraulic research laboratory in the Bureau of Standards have been reported out of committee in both the House and the Senate and will undoubtedly be brought to a vote soon after the tariff bill is out of the way. As they have the endorsement of all interested government agencies the outlook for their passage is favorable.

Secretary Wallace in presenting to the House Committee on Patents Council's attitude toward the Crampton Bill recommended an amendment to give technical men freedom to assist inventors.

Personals of A.S.A.E. Members

Dr. George Kuehne, professor of agricultural engineering, Technical Academy of the State of Bavaria, Munich, Germany, is author of "Handbook of Agricultural Machinery," just published by Julius Springer, Berlin, for students, engineers and mechanics. It is published in German.

E. W. Lehmann, professor of farm mechanics, University of Illinois, will address a conference of Illinois farm leaders and public utility executives at Springfield on March 20, on the progress made in rural electrification development in that state. The conference is being sponsored by the state agricultural and public utility organizations. An exhibit showing the application of electricity to various types of farming in Illinois will be a feature of the conference.

J. K. MacKenzie, formerly assistant superintendent of the Dominion Experimental Station at Swift Current, Saskatchewan, Canada, has accepted a position with the Caterpillar Tractor Company as agriculturist for western Canada.

E. H. Neal, has resigned as irrigationist of the Idaho Agricultural Experiment Station and instructor in agricultural engineering at the University of Idaho to accept a position as manager of the Aberdeen-Springfield Canal Company at Aberdeen, Idaho.

H. W. Riley, head of the department of rural engineering, Cornell University, and **D. E. Blandy** of the New York State Power and Light Corporation are members of a board of judges to decide the winner of a farm essay contest on the subject "How Electricity Helps the Farmer." The contest is sponsored by the General Electric Company.

G. E. P. Smith, professor of irrigation engineering, University of Arizona, delivered an address December 15, 1928, before the Arizona State Bar Association, entitled "An Equitable Basis for Solution of the Colorado River Controversy." This address has been reprinted and copies may be obtained by writing Dr. Smith at the University, Tucson, Arizona.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the February issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Charles F. Bateholts, farm electrification adviser, General Electric Co., Schenectady, N. Y.

Chester L. Berggren, instructor in farm buildings, University Farms, St. Paul, Minn.

Harry E. Besley, graduate student, University of Maryland, College Park, Md.

Herbert S. Eastwood, sales manager, The De Laval Separator Co., New York, N. Y.

Ralph W. French, director of agricultural sales, French Tractor & Equipment Company, Springfield, Ill.

James G. Klemgard, wheat ranch manager, Pullman, Wash.

Homer C. Mauer, junior agricultural engineer, U. S. Department of Agriculture, Washington, D. C.

Harlo A. von Wald, assistant agricultural engineer, United Fruit Company, Tiquisate, Estacion Rio Bravo, Guatemala, Central America.

Clyde Walker, assistant professor, Oregon State College, Corvallis, Ore.

New A.S.A.E. Members

David A. Bebinger, designer, J. I. Case Co., Rockford, Ill.

Alesander L. Dmitrieff, consulting engineer, Amtorg Trading Corp., 261 Fifth Ave., New York, N. Y.

Raymond R. Drake, junior agricultural engineer, U. S. Department of Agriculture, Hays, Kans.

Orville F. Drennan, designing engineer, Deere & Mansur, Moline, Ill.

Willard J. Durkee, salesman, J. I. Case Co., Trenton, N. J.

Francis D. Fogarty, managing director, Australia Farmers C. D. Harvester Works, Ltd., Melbourne, Australia.

Herbert W. Hayes, agricultural field representative, Friend & Ferry Lbr. Co., Sacramento, Calif.

Henry Morgenthau, Jr., publisher, American Agriculturist, New York, N. Y.

P. A. Rasmussen, research engineer and draftsman, Waukesha Motor Co., Washington, Neb.

Walter E. Selby, special salesman, John Deere Plow Co., York, Neb.

Harry D. Thorn, manager of sales promotion, Chicago Mill & Lumber Corp., Chicago, Ill.

Transfer of Grade

Arthur W. Farrall, research and development engineer, Douthitt Engineering Co., Chicago, Ill. (Associate to Member.)

Harry Miller, instructor in agricultural engineering, Rutgers University, New Brunswick, N. J. (Junior to Associate Member.)

Employment Bulletin

An employment service is conducted by the American Society of Agricultural Engineers for the special benefit of its members. Only Society members in good standing are privileged to insert notices in the "Men Available" section of this bulletin, and to apply for positions advertised in the "Positions Open" section. Non-members as well as members, seeking men to fill positions, for which members of the Society would be logical candidates, are privileged to insert notices in the "Positions Open" section and to be referred to persons listed in the "Men Available" section. Notices in both the "Men Available" and "Positions Open" sections will be inserted for one month only and will thereafter be discontinued, unless additional insertions are requested. Copy for notices must be received at the headquarters of the Society not later than the 20th of the month preceding date of issue. The form of notice should be such that the initial words indicate the classification. There is no charge for this service.

Men Available

AGRICULTURAL ENGINEER, six years power farming experience, graduate of a state university, two years post-graduate experience in research work on farm machinery and teaching experience in university. Will have master's degree in summer 1930. Age 29. Married. Position in corn belt preferred. MA-169.

AGRICULTURAL ENGINEER also trained in accounting, five years factory, selling, and office experience with large manufacturer. Prefers connection with engineering firm having some problems in accounting or finance, or with a concern engaged in the financing of agricultural projects. MA-171.

RURAL SERVICE ENGINEER, completing a fellowship in agricultural engineering in June, 1930. Graduate in electrical engineering 1928 and will have M. S. in agricultural engineering in June 1930. Two years experience in research work in rural electrification. American, unmarried, age 23. Junior Member A.S.A.E. Position with power or electrical appliance company preferred. MA-172.



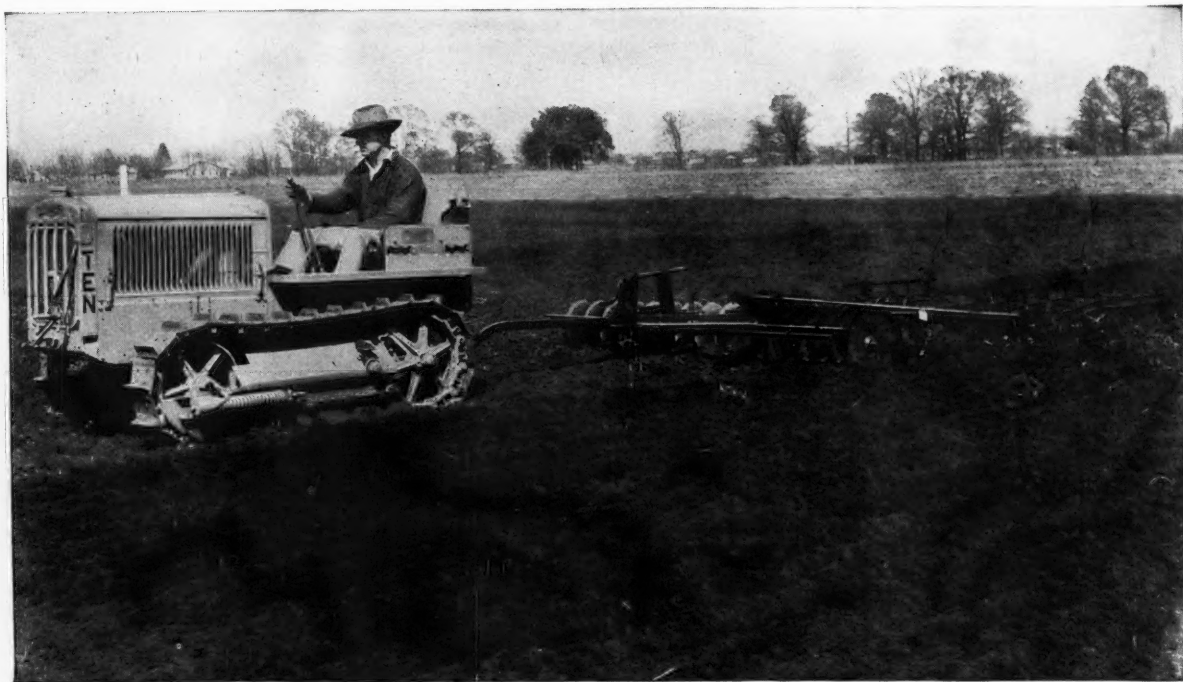
NEW DEPARTURE BALL BEARINGS

The Iron Horse of the farm was rid of rheumatism when New Departure Ball Bearings freed its shafts and gears of the drag and waste of friction. Power farm implements have been more mobile, tinker-proof and wear-proof since the natural law has been recognized that . .

CASE
EAGLE
UNITED
WALLIS
OILPULL
FARMALL
ALLIS-CHALMERS

BATES
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JOHN DEERE
ROCK ISLAND
McCORMICK DEERING

NOTHING ROLLS LIKE A BALL



Why different farmers buy "Caterpillar" Tractors

The orchardist requires traction that can pull his spray rig right after a shower—to turn in rank, damp cover crops without delay.

The corn grower needs a "Caterpillar's" light tread and sure traction to disk the mellow seed-bed until it's weed-free.

The vineyardist seeks power (and traction) to clean out a whole row at one trip.

The sugar beet farmer has found that sub-soiling shatters plow pan and brings a bigger tonnage—it takes rugged power and sure traction to pull a sub-soiler.

The truck farmer likes the "Caterpillar" because it maneuvers so easily in close quarters without "tramping" or side-slipping—and it earns for him all through the year.

The grain grower has learned that with its power and traction he can win his battles against the hazards of weather—to plow early and plant on time—to pull the combine in spite of soft fields.

Caterpillar Tractor Co.
PEORIA, ILL. and SAN LEANDRO, CALIF., U.S.A.
Track-type Tractors • Combines • Road Machinery
(There is a "Caterpillar" Dealer Near You)

CATERPILLAR
REG. U.S. PAT. OFF.
TRACTOR

Prices—f.o.b. Peoria, Illinois

TEN . . .	\$1100	TWENTY .	\$1900
FIFTEEN .	\$1450	THIRTY .	\$2375
SIXTY . .	\$4175		



Reducing Draft

IN a Combine light draft is secured through proper distribution of weight and correct wheel equipment. The Holt is equipped with French & Hecht Steel Wheels because they contribute not alone to light draft but to the satisfactory operation of the Combine as a whole. Some of the practical advantages French & Hecht Steel Wheels offer are:

1. They reduce draft to the minimum.
2. They provide proper ground contact and thus enable the Combine to function most effectively in varied field conditions.
3. They are designed for the most efficient type of bearing.
4. They are built to withstand all strain put upon them in service and to remain permanently true and rigid beyond the life of the machine.
5. French & Hecht construction assures not only a stronger and more durable wheel, but a wheel so exact mechanically that it adds to the efficiency of the Combine.

So efficient are French & Hecht manufacturing facilities, that a distinct saving in cost of wheels can be effected in most instances for manufacturers of any wheeled equipment. The vast engineering experience and facilities of this organization are always available to manufacturers. Write.



In French & Hecht Steel Wheels, the method of fastening spokes to hub and tire is a highly developed process. These wheels offer distinct advantages for farm implements of all kinds. . . . They are stronger and more durable than other types. There is no loosening of spokes and no yielding or distortion of wheel with continued use.

FRENCH & HECHT, Inc., Davenport, Iowa, Springfield, Ohio
Wheel Builders Since 1888

FRENCH & HECHT

STEEL WHEELS



Above: Wood Brothers Thresher with Carter Disc ReCleaner owned by Hirschmiller & Leonard, Hettinger, N. Dak.

At right: A pile of dockage on the ground which was removed by Hirschmiller & Leonard's thresher.



CARTER
DISC
ReCleaner

Performance Report No. 4*

CARTER DISC RECLEANER

On Wood Brothers Thresher

In order to have a Carter Disc ReCleaner on their threshers, many farmers and threshermen have bought new threshers with this equipment. Hirschmiller & Leonard bought a new machine last year just on this account.

"... So far this season we have removed 800 bushels of dockage with our Carter Disc ReCleaner. If we did not have a Carter on our new thresher we would have had to haul this dockage into town and give it away. On one job the dockage was coming out so fast that it piled up from the ground to the delivery spout.

"I would not have bought a new machine this year if it were not for the fact that I wanted one with a Carter Disc ReCleaner."

Farmers in the spring wheat areas want to clean their grain at the same time they thresh. Last year many of them waited until they could have it done on a Carter equipped outfit. Next year will see even a greater demand for threshers equipped with Carter Disc ReCleaners.

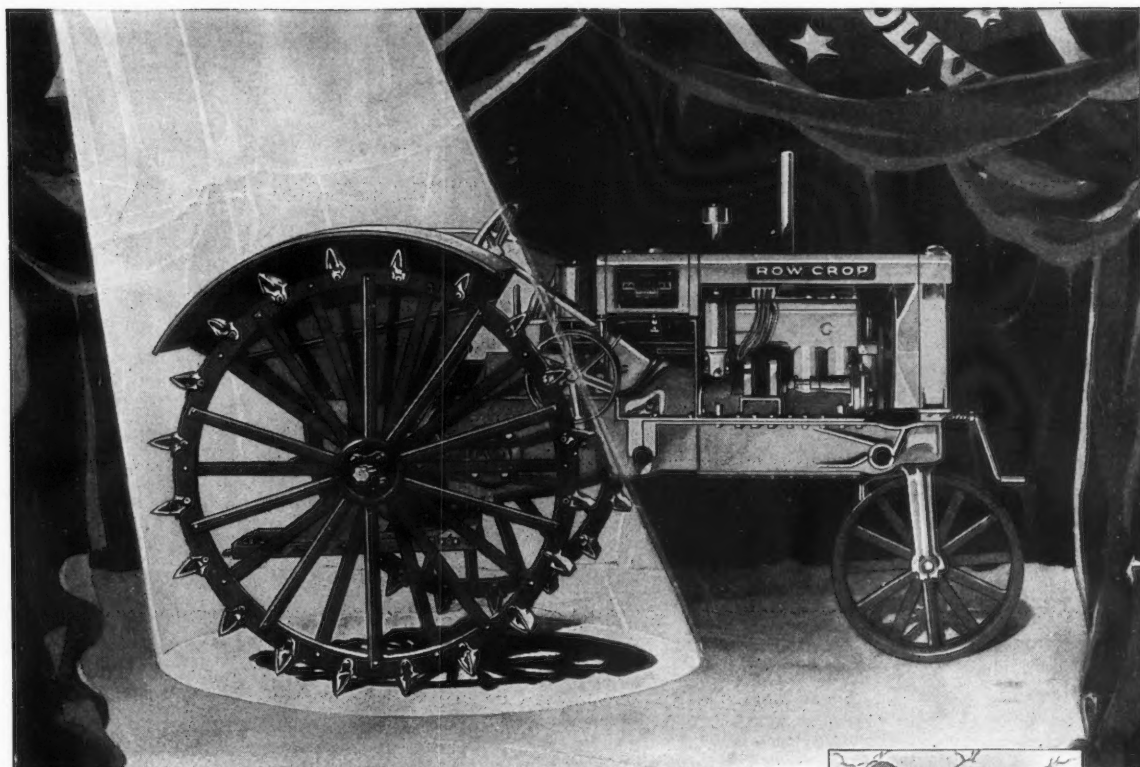
*Other Performance Reports have appeared in this magazine each month since December. Another will appear next month.

Carter-Mayhew Mfg. Co.

Division of HART-CARTER CO.

640 Nineteenth Avenue N. E., Minneapolis, Minn., U. S. A.

America's Largest Manufacturers of Grain Cleaning Equipment



HERE—*The New Oliver Hart-Parr "ROW CROP"*

They aren't just wheels,
they're a new way of applying power

Here it is, treading on tiptoe and pulling like a locomotive. Pulling, pulling, pulling, putting more of its developed power into traction than any tractor ever built before.

It's those wheels--those wheels that don't look like wheels--those wheels that do pull more efficiently, that do end soil packing, that do end side slipping, that do end wheel slippage. Pioneered by Oliver, they are new in design, new in size--and therein lies the secret of their power.

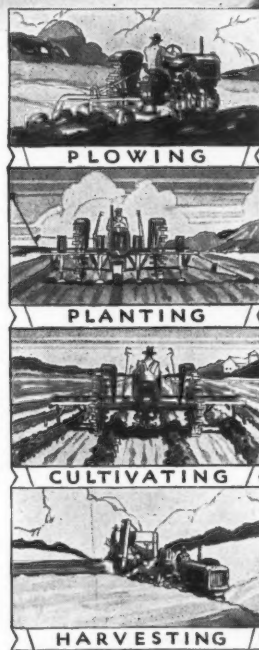
They aren't just wheels--they're a new way of applying power. Forget everything that went before.

Nothing like this has ever been seen before. Under the Oliver Flag--the Oliver Hart-Parr ROW CROP Tractor--the tractor that makes many tractors obsolete and will make horses only a memory on many farms. It's from the shops of Hart-Parr, Founders of the Tractor Industry. Send the coupon for complete information.



OLIVER

Farm Equipment Company
Chicago, Illinois



Write for
complete in-
formation to
the Oliver Farm
Equipment Sales
Company, 400 West
Madison St., Chicago, Ill.

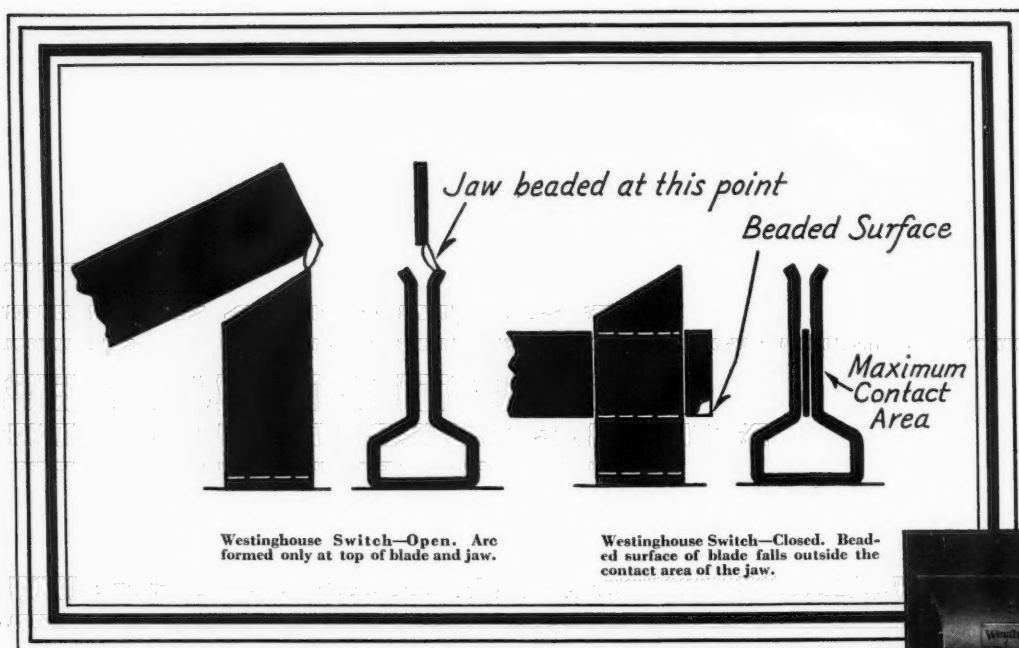
Name.....

Address.....

R. F. D. City.....

State.....

Branches everywhere to serve you



The Diamond Pointed Jaw gives a longer switch life

THE diagram shows how . . . and why the diamond pointed jaw and extended blade on Westinghouse Industrial Safety Switches prevent beading and burning of the jaw and blade, and give a cleaner, better contact. This better contact means that the temper of the jaw cannot be affected by overheating. It means an increased useful life of the switch.

The quick-make, quick-break mechanism; the arc quencher that quickly and effectively extinguishes the arc before it can damage the switch or endanger the operator; the simplicity of the Westinghouse design; and the facilities that assure prompt delivery of standard safety switches; also, contribute to the ever increasing popularity of the Westinghouse line.

Service, prompt and efficient, by a coast-to-coast chain of well-equipped shops

Westinghouse

T 31009-A



The Greatest Gift You Can Make Your Farm



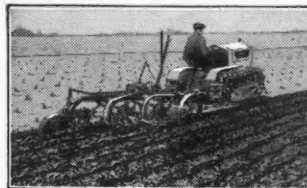
RIGHT now is the time when speedy, abundant, sure-footed tractor power can be turned into daily profit on your farm. With plowing to be done and seed beds still to be whipped into shape — with planting, orchard work, harvesting and scores of other big and little jobs still ahead for the coming months — there isn't a bigger gift you can make your farm today than the gift of a Cletrac.

You can buy this Cletrac "20" for Less Money than any other Twenty H. P. Tractor

Here is power for your heaviest implements — smooth, steady-pulling power that rides on broad steel tracks. Here is traction that holds in muddy fields and on steep hillsides. Here is speed that gets work done quickly. Here is unbelievable economy both in first cost and operating cost. Any way you measure it Cletrac offers you the greatest combination of farm advantages ever built into any farm tractor.

Cletracs are built in a complete line and priced as low as \$1095 F. O. B. factory. See the Cletrac dealer in your locality, or write direct for literature.

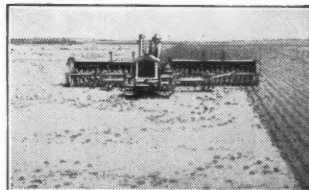
The Cleveland Tractor Co.
19318 Euclid Avenue Cleveland, Ohio



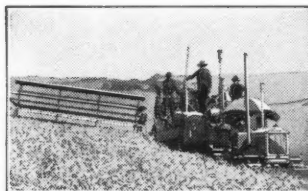
More acres per day at less cost per acre — that's Cletrac's plowing record.



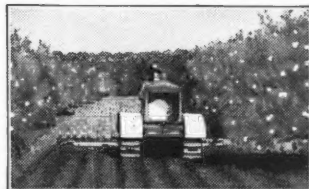
Fine seed-beds mean better yields. It's quick, easy work with Cletrac.



Cletrac's smooth, steady pulling and light tread assure perfect seeding.



Speedy abundant power is a harvest essential that Cletrac fully meets.



For orchard work Cletrac is supreme. Steep hills are its specialty.

Cletrac



ARMING ON A PRODUCTION BASIS ▲ ▲ ▲ ▲

THERE is an interesting analogy to the student of farm problems between it and the mining industry. Copper is copper and zinc is zinc just as corn is corn and wheat is wheat.

Yet many a mine is paying splendid dividends today on 1.4% ore when scarcely a score of years ago miners thought it didn't pay to go through the motions with less than 8% averages.

The mining industry has found its profits inside its own production costs. And one of its greatest savings has been developed in proper lubricated equipment.

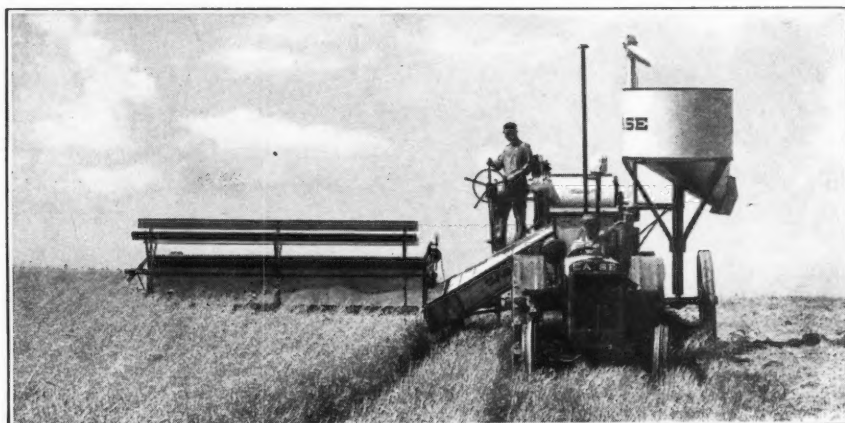
To farm on a production basis, even a small acreage, is to turn from abandoned methods of chance to modern methods of efficiency.

Here Alemite High Pressure Lubrication is playing a vitally important part. Farm equipment so fitted, lubricated with Genuine Alemite, shows gratifying profits to its owners. Break-downs are avoided, power demands are lower and deterioration is slowed up amazingly.

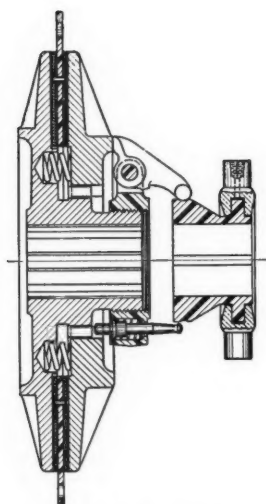
We have prepared for such students of agricultural efficiency as yourself special material well worth studying—material you will want to keep on file for constant reference. A line from you will bring it.

Alemite Corporation (Division of Stewart-Warner), 2656 N. Crawford Ave., Chicago, Ill.

ALEMITE
FARM LUBRICATION



Let This Salesman Work For You



PARTS STATIONS

Boston, Mass.—Rapp-Huckins Co., Inc.,
138 Beverly St.
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Cleveland—Industrial Engine Parts, Inc.,
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Chicago—Motive Parts Co. of America,
Inc., 2419 Indiana Ave.
Des Moines—Motive Parts Co. of America,
Inc., 1204 W. Grand Ave.
Detroit—Whitney Brothers, 6464 Epworth
Blvd.
Fort Worth, Tex.—Fort Worth Wheel &
Rim Co., 312 Throckmorton St.
Houston, Tex.—Portable Rig Co., Inc.
Knoxville, Tenn.—Automotive Equipment &
Supply Co.
Los Angeles—Coast Machinery Corpora-
tion, 464 E. Third St.
New York City—John Reiner and Company,
Inc., 290 Hudson St.
Philadelphia, Pa.—Maerky Machine Works,
632 Race St.
Pittsburgh, Pa.—A. H. Krigger & Co.
Smithfield & Carson Sts. Court 2496.
Raleigh N. C.—Motor & Equipment Co.,
215 E. Davis St.
San Francisco—F. Somers Peterson Co., 57
California St.
Seattle, Wash.—Pacific Hoist & Derrick
Company, 818 First Ave. South.
Tulsa, Okla.—Buda Engine Service Co. of
Tulsa, Inc.

SO far as performance goes, every tractor and combine built today by any reliable manufacturer, will do very satisfactory work.

Therefore, to sell your machines, you must know and talk about their outstanding *mechanical* features.

If your tractor or combine is equipped with a Twin Disc Clutch, you have several features to sell, of considerable value to your customers.

The Twin Disc Clutch is the easiest of all clutches to adjust. Any farmer can adjust it correctly, in the field if necessary, in less than five minutes. It cannot be thrown out of true, or otherwise damaged, by in-expert adjustment.

It has a fine quality of smooth engagement. This feature lightens the load on engine bearings and working parts. It lessens the need for and the expense of repairs. It contributes to day-by-day full capacity operation of the machine.

A Twin Disc Clutch on the machine can be used effectively to help you make tractor and combine sales. Let it work for you.



TWIN DISC CLUTCH COMPANY

RACINE

WISCONSIN

The Question of Proper Light for the FARM HOME

WHEN this question is asked of you—as an experienced Agricultural Engineer—you can recommend Carbide Gas plants for lighting, cooking and ironing with every assurance of complete satisfaction to the user.

Carbide Gas Plants are—

MODERN—Every advantage of the city home's lighting and cooking system can be had in Carbide Gas equipment. Up-to-the-minute fixtures and glassware, useful and beautiful, can now grace the rural home.

EFFICIENT—The finest light—nearest to sunlight in quality, for reading, study or diversion. Instant heat for emergency cooking and Carbide Gas ironing.

CONVENIENT—Lights for the home, barn and all outbuildings are available

always. The attention required by the plant will amount only to a few hours' total in the whole course of a year.

SAFE—Carbide Gas plants, made by members of this association, are listed as standard by the Underwriters' Laboratories, Inc. They are recommended by health and insurance authorities.

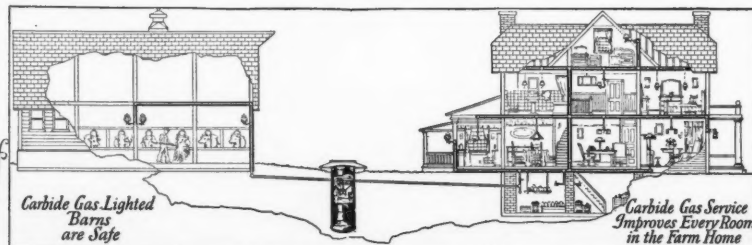
ECONOMICAL—The initial cost is no more than that of the lowest priced automobile. A charge of Carbide a few times a year is the only operating cost.

Agricultural Engineers are invited to write the Association for information, either general or specific, regarding Carbide Gas, its technical properties and installation data.



CARBIDE LIGHTING AND EQUIPMENT ASSOCIATION

176 WEST ADAMS STREET
CHICAGO, ILL.



Plowing Is Still the Biggest Job

*—and plow quality is as
vital as ever.*

PLOWING is the farmer's most important field work—the peak load of his farming—the biggest step in his crop production—just as it always has been and always will be.

Have you ever carefully watched the performance of a good mold-board plow?

Back and forth across the field, down in the stubborn earth, the plow works.

Think of the series of heavy, vital operations it performs, simply and accurately.

It cuts off thick, wide, heavy furrow slices uniformly...lifts them up...breaks them up and puts the soil into good physical condition...turns them over...tucks the trash under...lays the worked earth back uniformly in seed bed formation.

Thus, by a series of accurate processes the plow tames, for profitable crop growth, land that was lapsing toward a weedy waste.

No other farm implement or machine has more exact operations to perform. No other has such heavy work to do. Like the good

giants of old, the modern plow leads in taking from men the burden of heavy work and doing it with precision.

No wonder that the farmer has a warm spot in his heart for a plow that serves him well in doing his most important job!

John Deere plows have been winning good will among farmers for nearly a century. They were the first successful steel plows. They have "grown up" with agriculture in America. In most sections of the country, ever since the days of the early pioneers, John Deere steel plows have been the most widely used.

That record is due to the exceptional dependability of John Deere plows in giving the high-grade performance that farmers want in the most important of farming operations.

There are John Deere plows, for tractors or horses, in sizes and styles to suit every farm.

JOHN DEERE, Moline,
Illinois



The McCORMICK-DEERING Cream Separator

... a ball-bearing product of high and lasting quality in every detail—one of some sixty lines manufactured by International Harvester and dedicated to an industry which is daily demonstrating the truth of the slogan *Good Equipment Makes a Good Farmer Better*

—[International Harvester farm operating equipment is sold and serviced through McCormick-Deering dealers in all farming communities.]—

INTERNATIONAL HARVESTER COMPANY

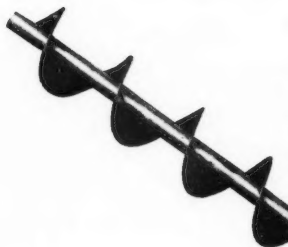
606 So. Michigan Ave. of America Chicago, Illinois
(Incorporated)



McCORMICK-DEERING Ball-Bearing Cream Separators

Specify . . .

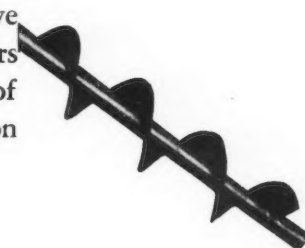
Genuine Caldwell Helicoid *Standard of the Agricultural Industry for 40 Years*



MORE than ever before the farmer is interested in the durability of the machine he buys. Strong, accurately formed flights of Caldwell Helicoid contribute materially to this feature when included in the design of the machines requiring grain augers or screw conveyors.

Genuine Caldwell Helicoid is rolled in a continuous spiral from a single bar by special machines of Caldwell's own design.

This produces flights of great strength and accuracy without laps or rivets to wear out or interfere with the smooth, easy flow of materials. These Caldwell Conveyor characteristics have long been recognized by agricultural engineers and as a result the leading manufacturers of agricultural machinery have standardized on genuine Caldwell Helicoid.



H. W. CALDWELL & SON CO.

LINK-BELT COMPANY, OWNER
CHICAGO: 2410 West 18th Street





Have Your Farm Friends Seen "Health, Happiness and Hogs?"

Your members, students and friends will enjoy this 1,000-foot motion picture that emphasizes the McLean County System of Swine Sanitation; shows the pitfalls of old-fashioned hog lot methods and how to avoid them. From it, too, they can learn the wisdom of a definite Farm Plan. And they will be thrilled at the tender love story that brings together the hired man and the daughter of the farm owner.

Arrange to show "Health, Happiness and Hogs," to your own members. This picture increases interest in Farm Planning. Covers crop rotation. The

value of legumes. Shows how marketing on the hoof brings extra profits and, at the same time, fertilizes the farm.

"Health, Happiness and Hogs" is available to farm advisers, county agents, vocational teachers. All you need do is pay transportation charges one way and send attendance report. Releases are made in order of requests received. You are urged to write immediately for a list of open dates.

"Health, Happiness and Hogs" is not an advertising film.

KEYSTONE STEEL & WIRE CO., PEORIA, ILLINOIS

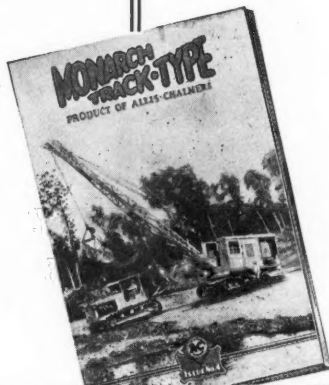
9470 INDUSTRIAL ST.

"Galvannealed"
not Galvanized

Always look
for the
Red Brand
(top wire)



Made in stiff
stay and hinge
joint style



We Will Be Glad to Send You This Tractor Magazine

"Monarch Track-Type" is issued at frequent intervals to show the kinds of work that is done with Monarch Tractors. The story is always told in pictures. We will be glad to put your name on the mailing list at no cost to you.

ALLIS-CHALMERS MFG. COMPANY
(Tractor Division)

615-62nd Ave., Milwaukee, Wis.

Specialists in Power Machinery Since 1846

Allis-Chalmers Mfg. Co.,
(Tractor Division)
615-62nd Avenue, Milwaukee, Wis.

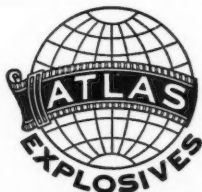
Please put my name on your list
to receive Monarch Track Type.

Name _____

Street Address _____

City _____

State _____



FARMEX EXPLOSIVES

Explosives have taken the backache out
of clearing and grubbing in farm fields

THE JOB, HOWEVER, IS AS YET UNFINISHED

Good farm engineering plans may well
specify Explosives for cleaning open
ditches and removing rock and boulders
from cultivated fields.

Agricultural Service Division

ATLAS POWDER COMPANY
Wilmington, Delaware



When a Louden Field Man Calls on a Farm Owner

to discuss farm buildings and equipment, he finds a ready welcome. The Louden name is one that every farmer knows, and in which he has confidence.

For more than 60 years Louden has been helping farmers everywhere, in America and foreign lands, to build better barns at reasonable cost—and to equip them for economy of time and labor—FOR PROFIT.

If, in your work, you have a problem that has to do with farm buildings or equipment, we shall be glad to collaborate with you through our own Agricultural Engineering Department.

THE LOUDEN MACHINERY CO.

6938 Court Street, (Est. 1867) Fairfield, Iowa, U.S.A.
Branches: Albany, Toledo, St. Paul, San Francisco

LOUDEN LABOR-**SAVING**
BARN EQUIPMENT

The Pickering Governor Co. ANNOUNCES A NEW TRACTOR GOVERNOR



New compactness of design. New responsiveness to load changes. Fully enclosed and protected from grit. Gear driven. Automatic lubrication.

Now in a unit only six inches in length and four inches in diameter, Pickering Engineers offer a new tractor Governor that incorporates the distinctive construction that for 68 years has made Pickering governors the world's standard for accuracy and dependability.

It may be installed vertically or horizontally, and is equipped with a simple and practical speed changer, for a wide range of motor speeds, which can be operated from cab or platform.

For complete information write Engineering Dept. E-1.

The Pickering Governor Co., Portland, Connecticut.
Governor builders since 1862.

PICKERING GOVERNORS

—SPLIT-SECOND



CONTROL

Professional Directory

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Engineers

Reports, Estimates, Valuations, Investigations,
Plans, Surveys, Supervision of Construction
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650 East Big Bend Blvd., St. Louis, Mo.

Mem. A.S.A.E.

WENDELL P. MILLER

Consulting Agricultural Engineer
and Architect

Drainage, Development and Management of Farms,
Country Estates and Golf Courses
85 East Gay Street, Columbus, Ohio

Mem. A.S.A.E.

THE LOUDEN MACHINERY CO.

Agricultural Engineering Service
For Farmsteads and Country Estates

Architectural development of country estates; complete planning and equipping of farm buildings; ventilation, heating, plumbing and sanitation. Land drainage and landscape development.

Fairfield, Iowa

Member A.S.A.E.

DRAWINGS FOR EVERY PURPOSE



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